

MASSACHUSETTS  
INSTITUTE  
OF TECHNOLOGY  
BULLETIN

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REPORT  
OF THE  
PRESIDENT  
1969



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**MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN**  
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## PRESIDENT

### I

**O**ne advantage in writing an annual report on one academic year after the beginning of the next is that the past has already become prologue and the future is already present. This is in keeping with the world in which, since my last accounting, an M.I.T. alumnus, assisted by an M.I.T.-designed guidance system, has been to the surface of the moon and back. Accordingly, though I shall glance over my shoulder occasionally at the year that has passed, I shall devote this report to this year and the years to come.

The individual reports of the Provost and the other academic and administrative officers, as usual, provide the full and stirring account of a year that, by and large, was an outstanding one in M.I.T.'s history.

The Institute, as we all know, has traditionally been deeply involved with the active concerns of contemporary man. In the past, these concerns entered the campus principally through the research and other interests of individual faculty members. Today they are swarming in upon us through every door and window and influencing the thinking and behavior of the community as a whole and of every one of us here, from the youngest freshman to the president. This represents a profound change in the role of the American university. Today, society — inside the university as well as outside it — is looking to this institution as both a model and a catalyst for social change. Because the university is the closest to the young, it, of all institutions, is easily the most receptive to change and to new ideas.

Today, our students and our faculty are working to see that M.I.T. lives up to its obligations to society, both as an example and as a participating citizen. That we must strive to live up to this potential, I

would submit, has never been in doubt. But how we are best to define and meet these high standards has never been so hotly debated on this campus.

We have had a year of accelerated energy at M.I.T. Our metabolism of ideas, events, and changes has been higher than at any time in my memory. We have had instances of sharp conflict, to be sure, but despite them, and in some ways because of them, we have been making measurable progress.

The conflict is inevitable. Whenever men grapple with oversized issues — as we now must — the temperature rises in proportion to the energy required. Strong commitment presupposes deep personal feelings, and, in a large community such as ours, we are bound to see a clash of different ideals, objectives, and visions. But these same feelings provide the driving force to overcome the inertia of the past — to reform what has lost its usefulness, to renourish the part that gives life to the present, and to invent new ways and new alternatives to cope with the future.

In such an atmosphere of conflict and change, our key question becomes: Will we be wise enough and reasonable enough to choose the proper course for action, and to move along it together toward real and lasting progress?

## II

Within the context of this question, I would like to raise some issues that help define the task of M.I.T. in the years ahead and to try to indicate what our approach should be in their resolution.

1. Can the campus — this campus — remain open to learning at a time when polarized views and political tendencies strain the delicate ties of trust and tolerance which form the basis for free and open exchange?

It is impossible to answer this question with assurance, but there are two reasons why the future may produce a hopeful response. First, we have come through the tests of the past academic year with considerable confidence in the resilience of the Institute. Faculty, students, administration, Corporation members, and alumni have all shown a commendable ability to accept change supported by reason, despite the noisy distractions that often surrounded its advocacy. Second, we have found — through challenging it — how much inner strength M.I.T. possesses. Our common purpose has been strong enough to withstand repeated temptations to line up to do blind battle with each other over issues.

So far, this has been the case. What will happen from now on, I do not know. Our community has a strong conviction that disagreement

with the views of others, if carried beyond vigorous criticism to irresponsible attack, could easily destroy our increasingly open university. There is a determination on the part of the faculty, students, and staff to see that this does not happen. There is a determination to see that the clash of ideas, which is perforce more prevalent on a campus than elsewhere — for this is what a university is all about — does not degenerate into coercive acts by anyone. This determination will have a difficult time prevailing on the campus, when in the world outside, we increasingly see disagreement escalate into confrontation and confrontation escalate into an exercise in brute force.

If what we are trying to protect through this period of great conflict and chaos is an open university, we must be sure that we practice what we preach. We must make sure that what we profess to be open is, in fact, open. This leads to a second, related concern.

2. Can we respect personal rights, and can we establish a system of justice and a sense of fairness which will survive the test of these super-charged times?

One step, of course, is to make sure that the university is a sensitive institution. The university structure exists to protect a system of due process, not to make it difficult. The hallmarks of bureaucracy — the bigness, the impersonal rules, the apparently impenetrable thicket of administrative layers and procedures, the unknown and faceless operators of the system — all these are hindrances both to justice and to an open university.

We must work, in the days ahead, toward strengthening the judicial system, toward developing a new code and process. If everyone in the M.I.T. community could feel that he would get a fair hearing for his complaints and action when it is warranted, the need for confrontation would vanish for all except the small number who may want confrontation for its own sake. The key words are, of course, "action when it is warranted." This is subject to a whole range of interpretations, and I believe that we will be struggling with this question for some time to come.

We have begun to deal with the question of individual and institutional rights in a very new sense during the past year. We have seen how the tyranny of either a majority or a minority can threaten the foundations of trust which make a democratic society work. One of the dangers in a polarized atmosphere is that strong feelings tempt one to override consideration for the rights of others. We cannot allow this to happen at M.I.T. We must not jeopardize the unwritten compact that holds any university community together: that here, above all other places in our society, is a refuge from the censor, where any individual can pursue truth as he sees it, without interference by any man or any group.

I have concentrated on these points — that the Institute is, and must remain, an open place for change, for the free pursuit of knowledge, for the exchange of ideas, for the rights of individuals, and for the administration of fairness — because I believe that these intertwined issues of freedom are the most crucial issues of survival before the university.

But two other questions of major significance, related to the reform of the substance of our institutions and to their financial survival, must also be understood by all.

3. Can the academic apparatus cope with technological and ideological change and obsolescence, in a way that the educational process can stay relevant for the students and, at the same time, retain its intellectual integrity; can it stay supportive for the faculty; can it stay responsive to the broader needs of our other constituencies?

These questions relate to the broad intellectual challenge, not only for M.I.T., but for all universities. If we believe that this institution, built around the trail-blazing force of science, must be especially sensitive to educational improvement, then there is large work to be done. The pressure from students in this area is strong and growing. And it is clear that a majority of the faculty would agree that we could do with considerable curriculum reform. We must be careful, as we conduct this reform, that we do not give in to those who believe that contemporaneity is the most important yardstick by which to measure most things, including intellectual pursuits. But many of the ideas from students show insight; they are constructive and I welcome them.

The faculty in general, with and without student help, is reorganizing its fields, moving into new areas, and trying new multidisciplinary approaches to old problems, such as urban affairs, public policy studies, and pollution and environmental control.

Department heads and faculty members are asking questions, of themselves and of the Institute, on the aims of education and research. Let me give you an example of one of these issues. I believe that M.I.T. must assert as large an influence on the results of technology as it has on its development, and this concern for end results must enter the teaching as well as the research process. I commented on this matter three years ago in my first speech as president: "I believe that the general range of problems attacked by M.I.T. in the future will shift more and more to those that understandably affect the ways in which our society lives, that this institution will increasingly exert its power toward problems of human significance . . . The university can make a powerful contribution toward the solution of these problems, and I must add that these are the problems which attract the best and most vigorous effort of our socially conscious youth."

PRESIDENT

That change has shown itself in the research and teaching efforts of the applied departments and of the extracurricular interests of students and professors alike. That change is now showing in the two large special laboratories — Lincoln and Instrumentation — for which M.I.T. has assumed responsibility in the national interest. The achievements of these distinguished places for research, and their contributions to research in defense technology are a matter of record. The Instrumentation Laboratory's accomplishments in the guidance and navigation problems of space exploration, most recently in the Apollo 11 flight, have been applauded by the world.

For some time the M.I.T. community — students, faculty, and the Corporation — has been concerned by the Institute's close relationship to these two laboratories, heavily oriented as they are toward defense sponsorship. Last spring, I appointed a review panel, chaired by Dean William F. Pounds, to examine this relationship. The panel's first report in May recommended a substantial change in the balance of the work done by the laboratories toward social and domestic problems. I do not underestimate — and neither did the review panel — the need for continued effort in defense technology. This effort is part of our responsibility to the nation, and I believe that this responsibility should continue.

I give this brief review of our relationship to the laboratories as part of the agenda of basic reappraisal now required at the Institute. On a broad scale, we must undertake now the review and improvement of our whole effort: the examination of the system of learning at M.I.T., the scope of the Institute's academic coverage, the centrality of science at the Institute, the size and character of the student body, the relationship between students and faculty, and our whole decision-making process. Such a base-point review was conducted at the time of the Lewis Commission, which completed its studies in 1949. Now once again we must take a hard look at the basic nature and purposes of our M.I.T. education. The need for such full study became increasingly apparent in the spring of 1969, when the faculty Committee on Educational Policy, and eventually the whole faculty, considered and then rejected small-scale revisions in the core curriculum.

A planning committee, headed by the Chairman of the Faculty and including both faculty and students, has completed a plan for the new M.I.T. Commission, recommending that it be given a very broad charter to map the future course of M.I.T. It has asked me to give the Commission the following charge:

To reconsider and reformulate the goals of the Institute in its commitment to knowledge and its relation to society; and to determine how the pursuit of these goals should affect such primary policies as the priorities and size limitations of the Institute and its directions for future growth;

## PRESIDENT

To reexamine the principles and methods of education, research, and administration which have evolved at the Institute, to judge which are still applicable and where changes will be required to meet the conditions of the coming era;

To propose such modifications in the Institute's environment and self-regulating arrangements as are necessary to assist each member of the M.I.T. community in his personal development and in his ability to contribute to the common purposes of the Institute with dignity and integrity.

This task will command the energies, ambitions, and enthusiasm of the entire M.I.T. community for some time to come. It will be a process of analysis, creativity, and debate. It will be an exercise in effective cooperation; all elements of the student body and faculty will be involved. Above all, it will be a challenge to our wisdom and our vision. If we succeed, future generations of M.I.T. students and teachers will remember this time as one of significant gain.

4. I must turn now to a final question, where optimism is hard to generate at this particular moment. Can the university maintain its vitality and momentum in the face of our present financial crisis? Every student and parent knows what is happening to tuition rates these days. M.I.T., like other institutions, had to announce this year an increase in its tuition — to \$2,500 — to be effective in 1970-71. We are suffering, as everyone is, from the pressures of inflation. But, more than this, the increase in tuition reflects the growth of our educational expenditures, primarily those for faculty salaries and for expansion of teaching into new fields. Even before the threat of new tax legislation, which could have disastrous effects on gift and grant support, it was clear that new sources of support had to be found. There must be a new and higher level of gift support from our friends and new types of support from the Government. At the present time, the outlook is not encouraging from either quarter.

I have been speaking, of course, of the instructional costs of higher education. On the research side, the continued erosion in Federal support for advanced work is now a matter of grave concern. The lack of adequate support for ongoing fields and the unavailability of funds for new and promising areas will lead inevitably to loss of momentum, missed opportunities, and gaps in the ranks of educated professionals. In the sciences, the long-run effects of such a drastic slowing down of Government support will approach the level of a national retreat, if not soon relieved. I shall continue to speak out on this subject, which I believe to be a basic responsibility for M.I.T. in the world of education.

## III

This has not been a traditional annual Report of the President, but this has not been an ordinary year. There is one part which is traditional,

#### PRESIDENT

however, and which I cannot omit. This year 12 distinguished men retired from the community: Professor Douglass V. Brown, Management; Professor Cecil G. Dunn, Nutrition; Professor Billy E. Goetz, Management; Professor Robert S. Harris, Nutrition; Professor Lawrence J. Heidt, Chemistry; Professor Yuk-Wing Lee, Electrical Engineering; Professor Kurt S. Lion, Biology; Professor Philip M. Morse, Professor of Physics and Director of both the Computation Center and the Operations Research Center; Professor Norman J. Padelford, Political Science; Professor Francis O. Schmitt, Institute Professor in the Department of Biology; Professor Thomas K. Sherwood, the first du Pont Professor of Chemical Engineering and Dean of the School of Engineering from 1946 to 1952; and, Professor Cyril S. Smith, Institute Professor in the Departments of Metallurgy and Humanities. These men, who are retiring with honor, will fortunately remain active in this learning community. Their work in teaching and research bears the mark of their creative and youthful minds. Their long service to the Institute and to generations of M.I.T. students is a remarkable expression of lives of quality and value.

Another great man must be mentioned here as well. In 1967, Charles Stark Draper retired from the faculty, but, at the Institute's insistence, he continued as full-time director of the Instrumentation Laboratory. Now he moves from that post, remaining as technical director and senior advisor in the Laboratory he created.

#### IV

**T**he problems of these times are not simple and will not yield to simple solutions of any kind — political, technical, or human. Our nation is being tested on the campuses of our colleges. How we, all of us, in every part of every university, bear ourselves in this time will decide whether our institutions emerge stronger or weaker when this period of trial is over. The war, which all of us want to see end, will end. It is vital to our nation that it end soon. But what comes afterward is also important, and what comes afterward is being shaped by what we do right now. I believe that the opportunities for education will be stronger if we at M.I.T. can maintain, in these difficult times, a spirit in which the will to improve is combined with a blend of wisdom and compassion. There is much to be changed in our world — in both priorities and practice — and we can do much to change it. And we will, as long as the Institute emerges from the present into the future as a stronger community, more effective in providing opportunity and more dynamic in initiating change.

I take my final words from a student's poem which was read at the

PRESIDENT

Wellesley College commencement last May by a member of the graduating class. I think these words speak to the dilemma of all of us — individuals and institutions alike — in these challenging times.

*... We have no need of false revolutions  
In a world where categories tend to  
Tyrannize our minds  
And hang our wills upon narrow pegs.*

*... Earth could be fair  
And you and I must be free —  
Not to save the world in a glorious crusade ...  
But to practice with all of the skill of our being  
The art of making possible.\**

HOWARD W. JOHNSON

\*Nancy Schreibner, Wellesley College '69, 1969.

## STATISTICS FOR THE YEAR

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1968-69:

### REGISTRATION

In 1968-69, student enrollment was 7,764, an increase of only 34 over the 7,730 enrolled in 1967-68. This total was comprised of 3,955 undergraduates and 3,809 graduate students.

Graduate students who entered M.I.T. last year held degrees from 277 colleges and universities, 173 American and 104 foreign. The foreign student population was 1,203, representing 15.5 per cent of the total enrolled. The foreign students were citizens of 80 different countries.

Degrees awarded by the Institute in 1968-69 included 808 Bachelor's degrees, 800 Master's degrees, 126 Engineer degrees, and 414 doctoral degrees — a total of 2,148.

### STUDENT AID

This year 2,337 undergraduates, 61 per cent of those enrolled, received \$2,744,432 in scholarship aid and \$2,009,931 in loans. These two categories of direct aid thus totaled \$4,754,363, an increase of 13 per cent over the year before.



#### PRESIDENT

The planned use of M.I.T. operating funds in the amount of \$298,990, to augment our designated scholarship resources during the past year, has helped to make possible this improved aid program. The scholarship assistance granted included \$1,174,528 from outside sources (an increase of 2½ per cent from the previous year) and \$1,270,914 from M.I.T.'s own endowment fund. The endowment for undergraduate scholarships was increased by \$2,248,078 during the year. Total endowment for scholarships now stands at \$18,305,678 reflecting a 14 per cent increase over 1967-68.

Of the loans provided undergraduates during the past year, \$502,341 came from the Institute's Technology Loan Fund, \$664,650 from the National Defense Student Loan Fund, and \$607,720 from other private loan funds administered by M.I.T. An additional \$235,220 in loan funds was received from other sources.

Beside the loan total recorded above, 225 students (graduate and undergraduate) received \$181,171 under the Installment Credit Program, which permits a portion of the tuition fee to be paid over a ten-year period.

During the academic year 1968-69, the Institute made the following awards to graduate students: \$3,044,335 in fellowships, traineeships, and scholarships; \$1,033,333 in staff tuition grants; \$6,014,943 in staff salaries; and \$645,965 in loans, for a total of \$10,738,576.

Comparable figures for last year were \$2,912,200; \$919,000; \$5,973,000; and \$618,000 respectively, for a total of \$10,422,200.

Fellowships awarded to our graduate students in 1968-69 by major outside agencies amounted to an additional \$1,949,528. The comparable figure for last year was \$1,996,600.

#### PLACEMENT

A total of 1,342 students took 6,075 interviews with 303 companies, 40 government agencies, and 12 graduate schools who visited the Placement Bureau during 1968-69.

Forty-two per cent of the total number of graduates entered business or industry, while 28 per cent of the degree recipients went on to further study. Among our graduating seniors, 47 per cent went on to graduate school, while 20 per cent entered industrial employment. Changes in these figures over last year could be due to the Selective Service Regulations. At the Master's level, 26 per cent went on to further study, while 35 per cent chose business or industrial employment. The per cent of doctoral candidates entering industry was 33, while 27 per cent chose to teach and 18 per cent went on to research.

A sharp increase was noted in the salary offers made; because of the

FIGURE 1  
FINANCIAL AID TO UNDERGRADUATE STUDENTS  
FROM ALL SOURCES, 1959-1969

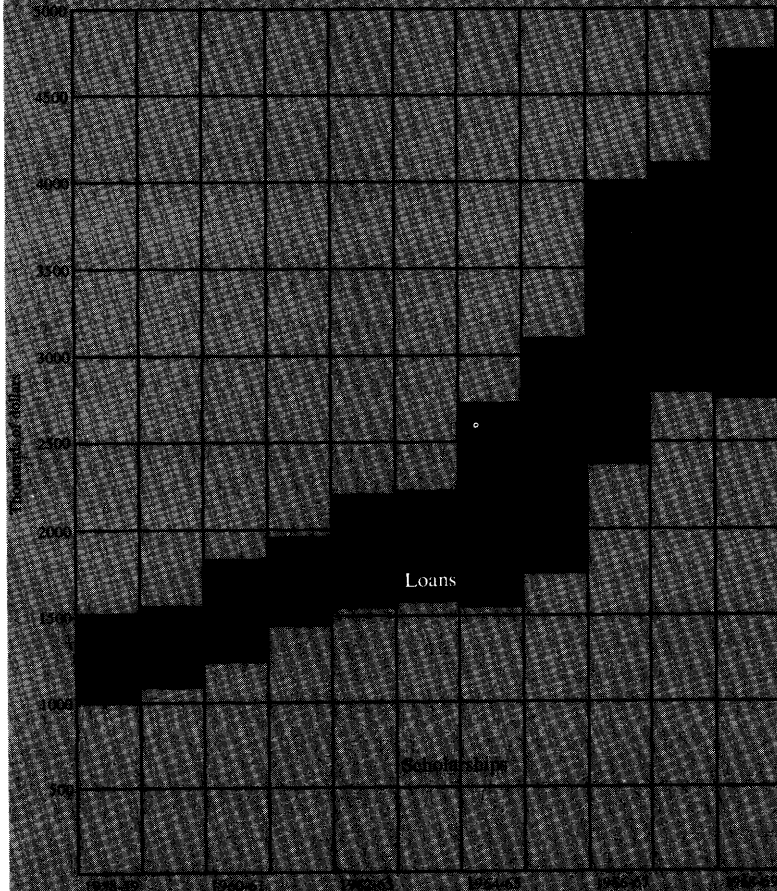
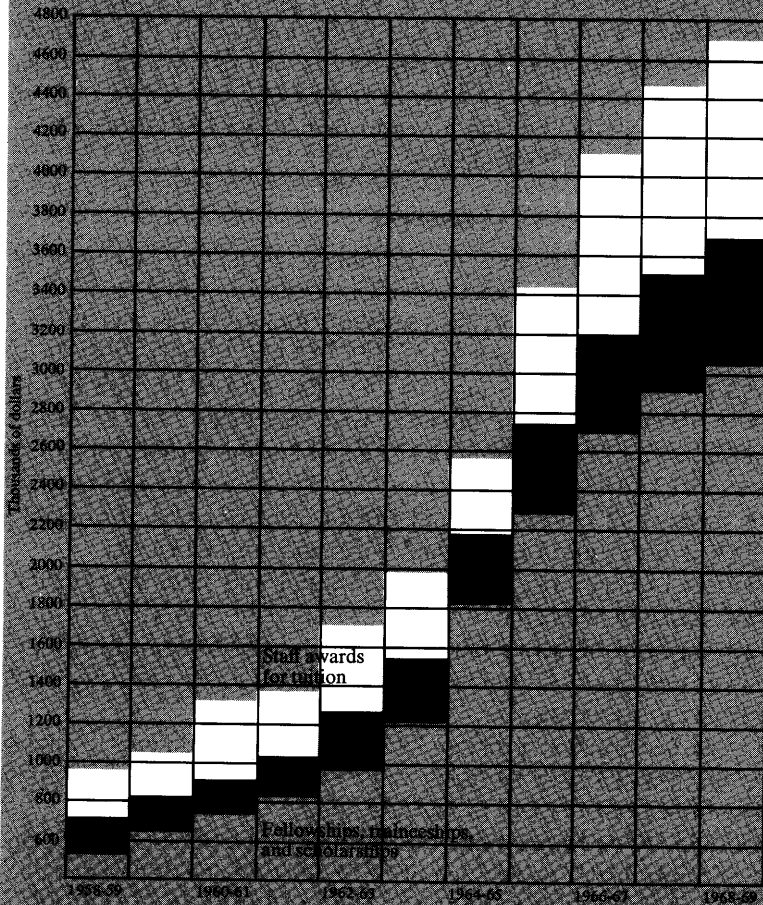


FIGURE 2

FINANCIAL AID TO GRADUATE STUDENTS  
AWARDED BY M.I.T., 1959-1969



inflationary trend, they are approximately 9 per cent higher than they were last year. The median offer to S.B. graduates was \$835; Master's recipients \$1,000, and doctoral candidates \$1,335.

In the Alumni Placement Bureau, the number of men registering for new positions increased by 4 per cent over last year. The significant difference between the groups is that this year a much larger number of alumni needed new positions because they expected to become unemployed. Another difference is that they were a little older than is usual — about 38, on the average, when traditionally they average 34 to 35.

This year the number of men with Ph.D.'s constituted 22 per cent of the alumni placement list. Last year it was 21 per cent. The number of placements made was up 11 per cent, partly because of the excellent quality of the available men, and partly because the requests for people, reduced by 22 per cent, relieved us of a normally impossible load of paper work. It is good to be able to report that 19 per cent of our placements were men with the Ph.D. degree.

#### FINANCES

As reported by the Treasurer, the Institute's educational and general expenses — excluding the direct expenses of departmental and interdepartmental research and of the Lincoln Laboratory and the Instrumentation Laboratory — amounted to \$57,355,000 during 1968-69 as compared to \$54,652,000 during 1967-68. The rate of increase of operations in 1968-69 over the previous year was below that of recent years, reflecting the limited resources available for the further expansion in educational and research activities. The Treasurer has pointed out that this increase in educational and general expenses was attributable primarily to adjustments in salaries and wages and related benefits.

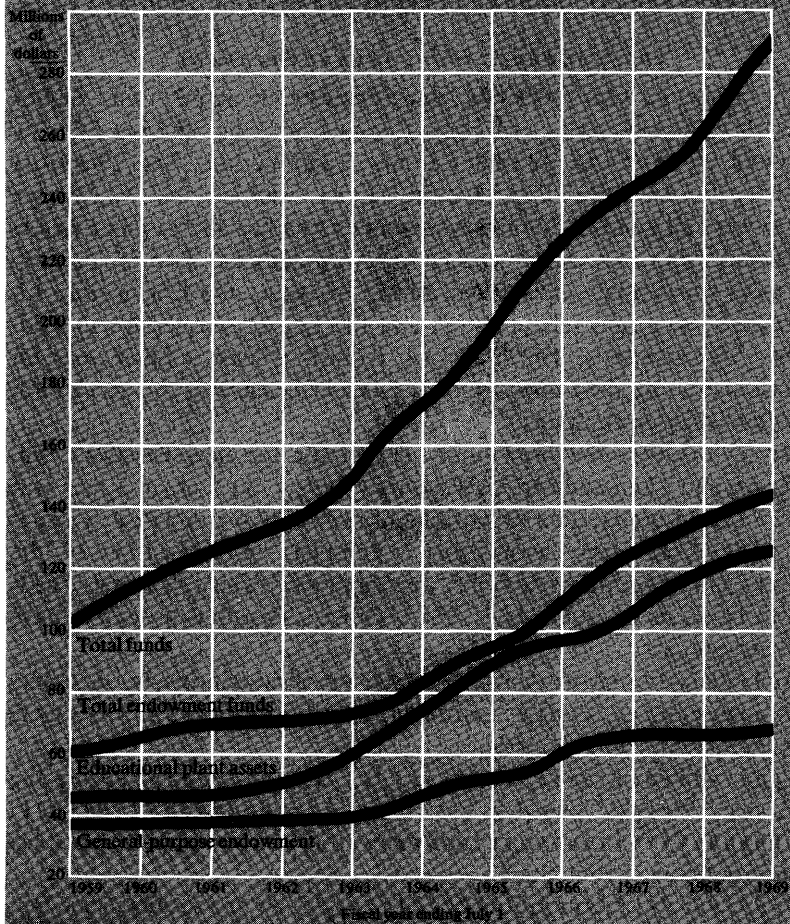
The direct expenses of general departmental and interdepartmental sponsored research increased from \$45,680,000 to \$45,812,000; and the direct expenses of major laboratories and special departmental research increased from \$106,678,000 to \$108,010,000, changing only slightly from the preceding year.

The large construction program of the Institute continued to make progress in 1968-69, with the book value of educational plant facilities increasing from \$120,197,000 to \$127,521,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, had a book value of \$276,300,000 and a market value of \$357,783,000. This compares to book and market totals of \$246,458,000 and \$354,744,000 last year. Endowment and other funds increased this year from \$259,882,000 to \$290,598,000.

Funds, sharing in the income from the general investments, earned

FIGURE 3  
THE GROWTH OF MLT'S FUNDS  
AND PLANT ASSETS, 1959-1969



## PRESIDENT

6.9 per cent, and 5 per cent was allocated to the endowment funds. In 1968-69, an extra distribution of 2 per cent was again made to these funds.

Figure 3 shows the growth of M.I.T.'s fund and plant assets from 1958 to 1969.

### GIFTS

Gifts, grants, and bequests to M.I.T. from private donors totaled \$29,652,-079.91 during fiscal year 1968-69, as compared with \$25,881,026.37 for the previous year. The former includes continuing payments on the Second Century Fund pledges of \$666,830.96, as well as unrestricted direct gifts to the Alumni Fund of \$744,000, which made up a part of the total of \$2,680,077 included in the Alumni Fund in 1968-69.

### PHYSICAL PLANT AND CAMPUS ENVIRONMENT

In the academic year 1968-69, new construction activity was slightly lower than in prior years, reflecting a gradual leveling off from the concentrated effort of the Second Century Fund period. The Chemistry Graduate Research Building, Hydrodynamics Addition, and MacGregor House were all delayed due to severe winter weather and to labor strikes connected with construction worker wage negotiations. Two major projects were substantially completed during the year: the Engineering Library renovation and rehabilitation and the Linear Accelerator in Middleton, Massachusetts. The latter will require at least another year for the installation by the Laboratory for Nuclear Science of the accelerator and other research equipment.

During the year the preliminary design for the new Electrical Engineering and Communications Research facility on Vassar Street was approved, and preparation of working drawings by the architect is under way. The preliminary layouts for a complete modernization of the Burton-Conner dormitory complex were approved. Construction is scheduled to begin in the summer of 1970. Other renovation programs have also been prepared.

Preliminary design work was initiated on several projects, including a 400-man graduate student apartment facility adjacent to the Westgate Married Student Housing complex.

Eighty individual space change projects were in progress during the fiscal year. Projects ranged in size from a simple partition change in Building 20, to the start of a major renovation and redesign of the third and fourth floors of Building 33.

Renovated classrooms in Buildings 4, 3, and 1 are the results of the first year of the Planning Staff's Classroom Renovation Program. Plans for the second year include the preparation of a program for the renovation of the lecture hall in 6-120.

PRESIDENT

M.I.T.'s physical environment has benefited from landscaping improvements made at East Campus, Senior Court, and Baker House. Plans for landscape projects include proposals for completing the Eastman Court as the new Chemistry Building is finished. In addition, the temporary plantings along Vassar Street at the Space Research and Information Processing Centers will be replaced with permanent tubs and plant materials.

**PERSONNEL CHANGES FROM  
OCTOBER 1, 1968, TO SEPTEMBER 30, 1969**

**FACULTY**

**DEATHS**

**JOHN W. M. BUNKER**  
Dean Emeritus of the  
Graduate School

**WALTER F. URBACH**  
Associate Professor Emeritus  
in Humanities

**RETIREMENTS**

**FRANCIS O. SCHMITT**  
Institute Professor

**CYRIL S. SMITH**  
Institute Professor

**DOUGLASS V. BROWN**  
Alfred P. Sloan Professor of  
Management in Sloan School  
of Management

**BILLY E. GOETZ**  
Professor in Sloan School  
of Management

**ROBERT S. HARRIS**  
Professor in Nutrition and  
Food Science

**YUK-WING LEE**  
Professor Emeritus in  
Electrical Engineering

**KURT S. LION**  
Professor Emeritus in Biology

**PHILIP M. MORSE**  
Professor Emeritus in  
Physics and Director,  
Operations Research Center

**NORMAN J. PADEFORD**  
Professor Emeritus in Political Science

**THOMAS K. SHERWOOD**  
Lammot DuPont Professor Emeritus  
of Chemical Engineering

**CECIL G. DUNN**  
Associate Professor Emeritus in  
Nutrition and Food Science

**LAWRENCE J. HEIDT**  
Associate Professor Emeritus  
in Chemistry

**RESIGNATIONS**

*Professors:*

**WILLIAM R. HAWTHORNE**  
Visiting Institute Professor

**CLYDE M. ADAMS JR.**  
Abex Corporation Professor of  
Metallurgy in Metallurgy and  
Materials Science

**FRANK BONILLA**  
Political Science

**JAMES G. GLIMM**  
Mathematics

**FRED C. IKLE**  
Political Science

*Associate Professors:*

**ROGER W. BROCKETT**  
Electrical Engineering

**SECOR D. BROWNE**  
Aeronautics and Astronautics

**LEROY L. CHANG**  
Electrical Engineering

**STEVEN A. COONS**  
Mechanical Engineering

**HENRI FENECH**  
Nuclear Engineering

PRESIDENT

**WILLIAM R. FERRELL**  
Mechanical Engineering

**GLEN E. GORDON**  
Chemistry

**DAVID M. HERCULES**  
Chemistry

**DEAN C. KARNOPP**  
Mechanical Engineering

**MILES KENNEDY**  
Sloan School of Management

**TAKESHI KOTAKE**  
Mathematics (to Visiting Professor)

**JAN LUBICZ-NYCZ**  
Architecture

**RONALD T. MCLAUGHLIN**  
Civil Engineering

**JUAN M. NAVIA**  
Nutrition and Food Science

**GERALD SILVERMAN**  
Nutrition and Food Science

**DAVID B. SMITH**  
Military Science

**JAY R. WALTON**  
Civil Engineering

**WAYNE A. WICKELGREN**  
Psychology

*Assistant Professors:*

**ARTHUR L. ANGER**  
Electrical Engineering

**VICTOR BARCILON**  
Mathematics

**NORMAN BLEISTEIN**  
Mathematics

**MANUEL BLUM**  
Mathematics

**GEORGE J. BORNSTEIN**  
Humanities

**MICHAEL J. BROWER**  
Sloan School of Management

**DENNIS D. BUSS**  
Electrical Engineering

**FRANK C. COLCORD JR.**  
Political Science

**WILLIAM E. DORENBUSCH**  
Physics

**JAMES W. DRYSDALE**  
Nutrition and Food Science

**ZIAD M. ELIAS**  
Civil Engineering

**JOSEPH GERSTMANN**  
Mechanical Engineering

**GEORGE E. HANSEN**  
Political Science

**CHARLES E. HUNT**  
Nutrition and Food Science

**PETER G. KATONA**  
Electrical Engineering

**DENNIS H. KLATT**  
Electrical Engineering  
(to Research Associate)

**WILLIAM J. KOSSLER**  
Physics

**ALAN J. LAZARUS**  
Physics (to Senior Research Scientist)

**WARREN J. MACISAAC**  
Economics

**C. DUNCAN MACRAE**  
Economics

**P. NARAYAN NAYAK**  
Mechanical Engineering

**JAMES W. OVERBECK**  
Physics

**JOHN F. PIERCE JR.**  
Sloan School of Management

**RONALD C. ROSENBERG**  
Mechanical Engineering

**KENAN E. SAHIN**  
Sloan School of Management

**JOHN D. STEINBRUNER**  
Political Science

**COLIN J. THOMPSON**  
Mathematics

**MICHAEL L. WIEDERHOLD**  
Electrical Engineering

**ROBERT D. YATES**  
Electrical Engineering

PROMOTIONS

*To Professor:*

**DOUGLAS P. ADAMS**  
Mechanical Engineering

**ALAN A. ALTSHULER**  
Political Science

**JAMES M. AUSTIN**  
Meteorology

**GLENN A. BERCHTOLD**  
Chemistry

**JOSEPH BICKNELL**  
Aeronautics and Astronautics



PRESIDENT

STEPHAN L. CHOROVER  
Psychology

ROBERT L. COBLE  
Metallurgy and Materials Science

JACK B. DENNIS  
Electrical Engineering

THOMAS H. DUPREE  
Nuclear Engineering

JOSEPH D. EVERINGHAM  
Humanities

AARON FLEISHER  
City and Regional Planning

MERTON C. FLEMINGS  
Metallurgy and Materials Science

JERRY A. FODOR  
Humanities

BERNARD J. FRIEDEN  
City and Regional Planning

BERNARD S. GOULD  
Biology

KENT F. HANSEN  
Nuclear Engineering

AUGUST L. HESSELSCHWERDT  
Mechanical Engineering

MARCUS KAREL  
Nutrition and Food Science

JERROLD J. KATZ  
Humanities

GORDON M. KAUFMAN  
Sloan School of Management

DANIEL J. KLEITMAN  
Mathematics

FRANCIS F. LEE  
Electrical Engineering

DEANE LENT  
Mechanical Engineering

PAUL W. MACAVOY  
Sloan School of Management

JAMES R. MELCHER  
Electrical Engineering

REGINALD E. NEWELL  
Meteorology

PAUL L. PENFIELD JR.  
Electrical Engineering

ROBERT R. RATHBONE  
Humanities

FREDERICK SANDERS  
Meteorology

IRVING SINGER  
Humanities

EUGENE B. SKOLNIKOFF  
Political Science

JOSEPH L. SMITH JR.  
Mechanical Engineering

PRESCOTT A. SMITH  
Mechanical Engineering

JUDITH J. THOMSON  
Humanities

RICHARD D. THORNTON  
Electrical Engineering

SAMUEL TING  
Physics

HARRY L. VAN TREES JR.  
Electrical Engineering

HAROLD Y. WACHMAN  
Aeronautics and Astronautics

EMMETT A. WITMER  
Aeronautics and Astronautics

GERALD N. WOGAN  
Nutrition and Food Science

*To Associate Professor:*

DAVID ADLER  
Electrical Engineering

THOMAS J. ALLEN JR.  
Sloan School of Management

STANFORD O. ANDERSON  
Architecture

THOMAS A. BELOTE  
Physics

SAMUEL W. BODMAN III  
Chemical Engineering

EDWIN D. BRANSOME JR.  
Nutrition and Food Science

RICHARD J. BRIGGS  
Electrical Engineering

WALLACE B. S. CROWSTON  
Sloan School of Management

MICHAEL J. DRISCOLL  
Nuclear Engineering

DUNCAN K. FOLEY  
Economics

LYNN W. GELHAR  
Civil Engineering

IRA S. GERSTEIN  
Physics

STEPHEN GROSSBERG  
Mathematics

PRESIDENT

**NORMAN D. HAM**  
Aeronautics and Astronautics

**WALTER M. HOLLISTER**  
Aeronautics and Astronautics

**ESTIL V. HOVERSTEN**  
Electrical Engineering

**WILLARD R. JOHNSON**  
Political Science

**DANIEL S. KEMP**  
Chemistry

**RENE P. V. KIPARSKY**  
Modern Languages and Linguistics

**THOMAS J. LARDNER**  
Mechanical Engineering

**BERNARD MASKIT**  
Mathematics

**TRAVIS R. MERRITT**  
Humanities

**BORIVOJE B. MIKIC**  
Mechanical Engineering

**DAVID B. MONTGOMERY**  
Sloan School of Management

**STEWART C. MYERS**  
Sloan School of Management

**ALAN V. OPPENHEIM**  
Electrical Engineering

**IGOR PAUL**  
Mechanical Engineering

**WHITMAN A. RICHARDS**  
Psychology

**JOSE M. ROESSET**  
Civil Engineering

**KENNETH C. RUSSELL**  
Metallurgy and Materials Science

**HERBERT W. SCHNOPPER**  
Physics

**MICHAEL S. SCOTT MORTON**  
Sloan School of Management

**MARLAN O. SCULLY**  
Physics

**JEREMY F. SHAPIRO**  
Sloan School of Management

**ROBERT J. SILBEY**  
Chemistry

**ALBERT SOLBES**  
Aeronautics and Astronautics

**DAVID H. STAELIN**  
Electrical Engineering

**STEVEN R. TANNENBAUM**  
Nutrition and Food Science

**KEITH I. THOMASSEN**  
Electrical Engineering

**DONALD R. UHLMANN**  
Metallurgy and Materials Science

**FREDERIC Y. M. WAN**  
Mathematics

**ANWAR E. Z. WISSA**  
Civil Engineering

**BERNHARDT J. WUENSCH**  
Metallurgy and Materials Science

**IOANNIS V. YANNAS**  
Mechanical Engineering

**SIDNEY YIP**  
Nuclear Engineering

*To Assistant Professor:*

**DAVID BOTSTEIN**  
Biology

**DAVID J. D'APPOLONIA**  
Civil Engineering

**THOMAS G. DAVIS**  
Electrical Engineering

**JEAN PIERRE FLATT**  
Nutrition and Food Science

**JONATHAN W. GREEN**  
Architecture

**ADOLFO GUZMAN**  
Electrical Engineering

**SAMSON T. JACOB**  
Nutrition and Food Science

**MILTON L. LAVIN**  
Sloan School of Management

**GEOFFREY MARGOLIS**  
Chemical Engineering

**ROBERT H. MAYER**  
Chemical Engineering

**DENNIS L. MEADOWS**  
Sloan School of Management

**MICHAEL S. PATERSON**  
Mathematics

**SAUL A. RAPPAPORT**  
Physics

**KENAN E. SAHIN**  
Sloan School of Management

**RONALD A. WALTER**  
City and Regional Planning

PRESIDENT

*To Assistant Professor and  
Postdoctoral Fellow:*

**BARRY A. BLESSER**  
Electrical Engineering

**CLARK K. COLTON**  
Chemical Engineering

**IAN T. YOUNG**  
Electrical Engineering

CHANGES OF APPOINTMENT

**RODNEY J. BAXTER**  
Assistant Professor in Mathematics

**RONALD A. BLANKEN**  
Assistant Professor in  
Nuclear Engineering

**AMAR G. BOSE**  
Clarence J. LeBel Professor in  
Electrical Engineering

**MICHAEL J. BROWER**  
Visiting Assistant Professor in  
Sloan School of Management

**GEORGE H. BUCHI**  
Dreyfus Professor in Chemistry

**BOYCE W. BURGE**  
Assistant Professor in Biology

**CHARLES T. COLE**  
Associate Professor in Humanities

**F. ALBERT COTTON**  
Dreyfus Professor in Chemistry

**HUW G. DAVIES**  
Assistant Professor in Mechanical  
Engineering

**PETER H. ELBOW**  
Assistant Professor in Humanities

**EDWIN R. GILLILAND**  
Warren K. Lewis Professor in  
Chemical Engineering

**JAMES W. GOSNELL**  
Assistant Professor in Nuclear  
Engineering

**HANS GUGGENHEIM**  
Visiting Associate Professor in  
Humanities

**ALLAN F. HENRY**  
Professor in Nuclear Engineering

**FRANK S. JONES**  
Professor in Civil Engineering

**NORMAN A. KURNIT**  
Assistant Professor in Physics

**T. WILLIAM LAMBE**  
Edmund K. Turner Professor in  
Civil Engineering

**JOHN D. C. LITTLE**  
Professor in Sloan School of  
Management and Director of  
Operations Research Center

**FRANCIS E. LOW**  
Karl Taylor Compton Professor  
in Physics

**RICHARD A. MOSS**  
Du Pont Assistant Professor of  
Mechanical Engineering

**JAMES K. PALMER**  
Associate Professor in Nutrition and  
Food Science

**SEYMOUR A. PAPERT**  
Professor in Mathematics

**BARRY B. SPACKS**  
Associate Professor in Humanities

**GEORGE W. RATHJENS**  
Professor in Political Science

**JOHN C. SHEEHAN**  
Dreyfus Professor in Chemistry

**STEVEN WEINBERG**  
Professor in Physics

**MINOR WHITE**  
Professor in Architecture

APPOINTMENTS

*Professor:*

**MICHEL BARANGER**  
Physics

**EDWARD H. BOWMAN**  
Sloan School of Management

**ARNOLD L. DEMAIN**  
Nutrition and Food Science

**HERBERT J. GANS**  
City and Regional Planning

**DAVID D. LANNING**  
Nuclear Engineering

**WILLEM V. MALKUS**  
Mathematics

**FREDERICK G. WORDEN**  
Medical Department and Program  
Director of Neurosciences Research  
Program

*Associate Professor:*

**JACK E. BALDWIN**  
Chemistry

**EMILIO BIZZI**  
Psychology

**STEVEN KLEIMAN**  
Mathematics

PRESIDENT

ROBERT S. LEES  
Nutrition and Food Science

MICHAEL LIPSKY  
Political Science

JEAN F. LOUIS  
Aeronautics and Astronautics

HAROLD O. McEACHERN  
Naval Science

REGIS M. N. PELLOUX  
Metallurgy and Materials Science

UTTAM L. RAJBHANDARY  
Biology

BRIAN B. SCHWARTZ  
Physics

ROBERT B. WILSON  
Nutrition and Food Science

*Assistant Professor:*

JAMES E. ANNABLE JR.  
Sloan School of Management

JOHN H. BEATON  
Naval Science

GEORGE F. BERTSCH  
Physics

STUART M. BLUMIN  
Humanities

GEORGE S. BOOLOS  
Humanities

DENNIS D. BUSS  
Electrical Engineering

WIT BUSZA  
Physics

JAMES D. CALLEN  
Aeronautics and Astronautics

CHARLES C. COUNSELMAN III  
Earth and Planetary Sciences

RENWICK E. CURRY  
Aeronautics and Astronautics

JAMES F. DRUMMOND  
Nutrition and Food Science

ROBERT F. ENGLE III  
Economics

NAZLI C. FIELD  
Political Science

MICHAEL J. FISCHER  
Mathematics

DEVENDRA P. GARG  
Mechanical Engineering

PHILIP J. GREENBERG  
Mathematics

RAYMOND H. GRENIER  
Aerospace Studies

RONALD E. GRIESON  
Economics

JOHN J. GUINAN JR.  
Electrical Engineering

JOHN HARBISON  
Humanities

JOHN HENIZE  
Sloan School of Management

PETER A. HOLLAND  
Athletics

WILLIAM J. INCE  
Electrical Engineering

ROMAN W. JACKIW  
Physics

ROGER E. KAUFMAN  
Mechanical Engineering

PAUL R. KLEINDORFER  
Sloan School of Management

JAMES V. KOHL  
Humanities

STEPHEN G. KUKOLICH  
Chemistry

AMOS LEVIN  
Aeronautics and Astronautics

DAVID M. LEVIN  
Humanities

DAVID C. MAJOR  
Civil Engineering

ROGER G. MARK  
Electrical Engineering

DAVID H. MARKS  
Civil Engineering

THOMAS R. MCGETCHIN  
Earth and Planetary Sciences

ALBERT R. MEYER  
Electrical Engineering

GORDON E. NELSON  
Modern Languages and Linguistics

WILLIAM M. RAND  
Nutrition and Food Science

NORALOU P. ROOS  
Political Science

CHRISTOPHER SCHAEFER  
Political Science

H. EUGENE STANLEY  
Physics

PHILIP THULLEN  
Mechanical Engineering

PRESIDENT

NEIL E. TODREAS  
Nuclear Engineering

ARTHUR P. L. TURNER  
Mechanical Engineering

ROY E. WELSCH  
Sloan School of Management

DAN S. WHITE  
Humanities

DANA E. WILSON  
Nutrition and Food Science

*Assistant Professors and Postdoctoral  
Fellows:*

LOUIS B. D. BRAIDA  
Electrical Engineering

JOHN W. DEVANNEY III  
Naval Architecture and Marine  
Engineering

MARTIN E. HELLMAN  
Electrical Engineering

RALPH L. KEENEY  
Civil Engineering

JIN-AU KONG  
Electrical Engineering

APPOINTMENTS OF VISITING FACULTY  
*Visiting Professors:*

LEV A. ARTSIMOVICH  
Karl Taylor Compton Professor  
of Physics

KENNETH B. CLARK  
Institute Professor

JULIAN BEINART  
Bemis Professor in Architecture

HERBERT C. BROWN  
A. D. Little Professor of Chemistry

DENISE LEVERTOV  
Abby Rockefeller Mauzé Professor  
in Humanities

RITA LEVI-MONTALCINI  
Abby Rockefeller Mauzé Professor  
in Biology

FORTUNATO T. ARECCHI  
Physics

ARTURO ARIAS  
Civil Engineering

ERNST BASLER  
Civil Engineering

JOANNES J. BEENAKKER  
Chemistry

PETER BERNHOLZ  
Economics

ARMAND BOREL  
Mathematics

RICHARD G. BREWER  
Physics and Chemistry

WILLIAM P. BUNDY  
Political Science

ALBERT BUSH-BROWN  
Architecture

CHAO K. CHOW  
Electrical Engineering

KAO-LIANG CHOW  
Psychology

CHARLES S. COX  
Earth and Planetary Sciences

JOHN P. CRAVEN  
Naval Architecture and Marine  
Engineering and Political Science

LOTHAR CREMER  
Mechanical Engineering

GIANCARLO DECARLO  
Architecture

EDSGER W. DIJKSTRA  
Electrical Engineering

RICHARD C. EXNER  
Humanities and Foreign Literatures  
and Linguistics

EDWARD FREDKIN  
Electrical Engineering

ROBERT E. GARIS  
Humanities

IMRE HALASZ  
Architecture

LILLIAN HELLMAN  
Humanities

HEINRICH HERTEL  
Aeronautics and Astronautics

BELA JULESZ  
Psychology

VLADIMIR KELLIS-BOROK  
Earth and Planetary Sciences

SANFORD A. LAKOFF  
Political Science

A. SCHEFFER LANG  
Civil Engineering

MARVIN S. MYERS  
Sloan School of Management

V. LAKSHMI NARAYANAN  
School of Engineering

PRESIDENT

KAZUO SATO  
Economics  
DONALD J. WHITE  
Sloan School of Management

*Visiting Associate Professors:*

CHARLES R. BENTLEY  
Earth and Planetary Sciences

DAVID E. BERLEW  
Sloan School of Management

TAYLOR L. BOOTH  
Electrical Engineering

LUIS ESTEVA  
Civil Engineering

HERMANN FLESSNER  
Civil Engineering

RALPH A. GAKENHEIMER  
City and Regional Planning

CHRISTOPH HABERLAND  
Aeronautics and Astronautics

MICHAEL A. HARRISON  
Electrical Engineering

PATRICK W. HOHEPA  
Modern Languages and Linguistics

THADHO S. JASEJA  
Physics

SPIRO KOSTOF  
Architecture

TED KRAYNIK  
Architecture

HANS WOLFGANG LEVI  
Nuclear Engineering

SANJOY K. MITTER  
Electrical Engineering

JOAN M. NELSON  
Political Science

JURGEN NEUKIRCH  
Mathematics

ATSUHIRO NISHIDA  
Physics

ARCHIE M. RICHARDSON JR.  
Civil Engineering

SURENDA P. SHAH  
Civil Engineering

JAY R. WALTON  
Civil Engineering

*Visiting Assistant Professors:*

LAURENCE S. CUTLER  
Architecture

MURRAY MILNE  
Architecture

WILLIAM K. PRATT  
Electrical Engineering

VISWANATHA RAGHAVAN  
Metallurgy and Materials Science

GABRIELE VENEZIANO  
Physics

KUNG YAO  
Electrical Engineering

ADMINISTRATION

DEATHS

OLIVE H. LIBITZ  
Staff Accountant  
Comptroller's Accounting Office

DANIEL G. WEBSTER  
Manager  
Campus Housing

RETIREMENT

FREDERIC W. FENERTY  
Purchasing Agent

RESIGNATIONS

JOHN B. ADLER JR.  
Administrative Assistant  
Campus Housing

LEW F. BOYD  
Assistant to the Director  
Development Office

EDWARD J. CAREY JR.  
Associate Director of Student Aid  
and Director of Undergraduate  
Employment

JOHN H. CARTER  
Institute Secretary

KAREN A. COHEN  
Planning Assistant

ARTHUR J. COLLIAS  
Industrial Liaison Office

HAROLD E. DREYER  
Personnel Officer for Benefits  
Office of Personnel Relations

THOMAS W. HARRINGTON JR.  
Director of Placement

KARL B. KEHLER  
Industrial Liaison Officer

**PRESIDENT**

**WILLIAM J. KELLEY**  
Project Coordinator  
Institute Real Estate

**DAVID J. KNEELAND JR.**  
Assistant to the Director  
Student Aid

**LEONARD E. LYON**  
Systems Analyst  
Office of Administrative Systems

**WILLIAM H. MCTIGUE**  
Director of the Educational Council  
and Associate Director of Admissions

**DAVID MAURIELLO**  
Staff Accountant  
Comptroller's Accounting

**JEHANGIR J. MUGASETH**  
Architect-Planner  
Planning Office

**CHRISTOPHER C. MUNGVERN**  
Staff Accountant  
Comptroller's Accounting

**GLORIA D. NEL**  
Systems Analyst  
Office of Administrative Systems

**CARL H. NEU JR.**  
Industrial Liaison Officer

**RICHARD J. O'DONNELL**  
Subcontract Administrator  
Lincoln Laboratory Fiscal Office

**ROBERT OLINTO**  
Grants Accountant  
Office of the Comptroller

**MARY O'SHAUGHNESSY**  
Manager  
Endicott House

**ANN PETERSON**  
Administrative Assistant  
Alumni Association

**EDWARD T. PIEPER**  
Construction Manager  
Physical Plant

**RICHARD R. RANDLETT**  
Associate Registrar

**PAULINE S. SHIH**  
Staff Programmer  
Comptroller's Data Processing

**RICHARD N. SMILLIE**  
Associate Director  
Division of Sponsored Research

**PENELOPE R. STEVENS**  
Senior Programmer  
Office of Administrative Systems

**PETER T. VAN AKEN**  
Special Assistant  
Planning Office

**KERRY B. WILSON**  
Personnel Officer for Hourly Personnel  
Office of Personnel Relations

**APPOINTMENTS AND CHANGES**

**RICHARD P. ADELSTEIN**  
Special Assistant  
Provost's Office

**JANET B. ARTERTON**  
Community Development Assistant  
Planning Office

**ROBERT R. BABB JR.**  
Assistant Auditor

**RAYMOND F. BADDOUR**  
Head  
Department of Chemical Engineering

**PAUL F. BARRETT**  
Construction Manager  
Physical Plant

**CHARLES E. BARRINGER**  
Administrative Officer  
Department of Mechanical  
Engineering

**J. PETER BARTL**  
Industrial Liaison Officer

**MANSON BENEDICT**  
Institute Professor and Head  
Department of Nuclear Engineering

**C. FREDERICK BENTLEY II**  
Administrative Officer  
Department of  
Nutrition and Food Science

**VIRGINIA A. BISHOP**  
Personnel Representative  
Office of Personnel Relations

**LESLIE M. BORING JR.**  
Industrial Liaison Officer

**DOROTHY E. BOWE**  
Assistant to the Dean for Student  
Affairs  
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## SCHOOL OF ARCHITECTURE AND PLANNING

**M**.I.T., along with other long-established institutions not directly supported by tax revenues, is obliged by prevailing socio-economic conditions to restrain its growth; it does not participate in the quantitative explosion that characterizes higher education generally. The burden of dealing with the geometrically increasing numbers, not only of the college-age population, but of the growing percentage of this population who seek higher education, has shifted first to the state universities, then to the state college systems, and finally to the burgeoning junior colleges. As a result, the fractional share of the total educational load carried by private institutions like M.I.T. has markedly diminished in the last 20 years.

At first these private institutions, or at any rate those among them which, like M.I.T., have prominence and a national role to play, benefited by this turn of events. The vast increase in the number of possible candidates attracted to prestigious universities led to highly selective procedures not only in student admissions but also in faculty recruitment. With increasing selectivity, these institutions were presumed to achieve over the years higher and higher standards. Books have been written to identify and evaluate the rankings of the leading universities in their various fields of study, and much attention is paid in them to the relative excellence of the nation's top graduate schools.

In the areas of pure scholarship, elitism has indeed created centers of extraordinary quality. In departments that prepare for service professions such as planning and architecture, the advantages of high selectivity are less compelling, because other factors predominate in determining the course of development.

These professions have no insulation against the marketplace. What happens in M.I.T.'s School of Architecture and Planning cannot fail to be consistent with the changing status of the involved professions and with the educational trends that characterize the national roster of professional schools.

The phenomenon of higher education growing much faster than population has brought professional education to a new kind of watershed. Enrollment now exceeds the numbers needed to maintain professional cadres because it is determined instead by the careers young people wish to make for themselves. For the first time in our history there is one degree candidate enrolled for every two practicing degree holders, and the ratio continues to diminish.

Nor is the wish to avoid uncontrolled growth and to be selective a dependable defense against these trends. Two examples will suffice. The City Planning Department at Yale University is in crisis over the issue of admitting a larger proportion of black students to its graduate program. In September, Denmark's prime architecture school, the Royal Academy of Fine Arts, will change its admissions policy following a year of student riots. Instead of elaborate testing to select 150 new students, the school will henceforth admit all who technically meet certain academic criteria. It is estimated that 600 will apply every year, and the school will have to accommodate them without any increase in resources. Elitism is definitely under attack.

Our good fortune in not having been subjected to the extreme events occurring in distinguished sister institutions does not exempt us from exposure to very similar issues, but student insistence on the right to shape their own educational experience is leading, in the case of our Department of City and Regional Planning, in very constructive directions. There is no doubt that selectivity has been beneficial. This group is entirely composed of graduate students, almost half now doctoral candidates, whose previous academic achievements are outstanding and whose social commitment is always evident. Curriculum revision at their hands will be mature and responsible.

National enrollment in city planning schools continues its steep climb, doubling every four to six years, and some of this growth is reflected in the steady but slower rate of increase in M.I.T.'s City and Regional Planning. As it grows, this profession constantly broadens its range of concerns away from technical manipulations, and toward a broader study of the design of social policies, seeking to overcome the bewildering absence of firm knowledge about the reasons for success or failure of policy, and obsessed also with the need to involve citizens more fully in planning as it affects them.

One of the Department's practical concerns is to interact constructively with the ground swell of involvement in urban problems exhibited in other sectors of the Institute. Joint appointments in several departments and shared work in research are current modes of interaction. An interesting new one is embodied in the proposal for the S.B. in Urban Studies outlined in Professor John T. Howard's report.

The winds of change in the Department of Architecture carry fragrances of a somewhat different nuance. Here again we observe strong impulses toward self-determination by individual students. The adoption of a mechanism for "independent study projects," done for credit under faculty supervision, provides a valuable resource applicable to needs felt by the students. It contains the possibility of being effective as a way of learning, although results will not always be directly measurable. It risks alienating a teacher whose interests do not parallel the purposes of the student whom he supervises. It will take hard work to share the results of these studies, not to allow them to remain only in the private experience of their authors.

Architecture's program pierces more deeply into undergraduate life than does planning; its devotees also include some, even among the more mature, who view the world as a source of sensual experience. This doubtless explains behavior that may occasionally seem impulsive or irrational to other components of the academic community. But some of these tendencies may also be caused by impending professional tensions, whose nature is hard to define in a few words.

There is no question about our society's need for construction, nor of its will and capacity to build. Whether architects will be important in the process depends both on how building is to be done, under what conditions and for what purposes, and on the professional designer's response to a new kind of "how."

Small-scale, sensitively designed custom building is steadily becoming more difficult and less characteristic of our age. The pressure to industrialize building, the proven "heft" of mammoth diversified corporations, the intervention of Federal government, the need to aggregate markets, the success of conglomerate interprofessional megaconsultants — these take control out of the hands not only of the consumer, but also those of the designer, in his capacity as an individual person with an identifiable contribution.

Those who are entering the problematic profession of architecture show some tendency to polarize in two directions. One sector is enthusiastic to bring about a more scientific, more complex but at the same time more consistent and "plan-able" process. They embrace new methods of information processing and decision making. They enjoy teamwork and

collaboration with other professions, and they look forward to a time when all designs will be fully informed and rational.

The other sector looks critically at the self-discipline, the impersonality and the bureaucracy characteristic of the highly industrialized production of shelter and is not impressed with the delights of participating in these processes. So far, "systems" approaches to creating livable environments have provided results that are mostly negative. Our Levittowns, Restons, Prudential Centers, our new campuses like that at Irvine, do not cradle life as supportively as did the more primitive fishing villages of the Tyrrhenian, the Adriatic, and the Aegean, for all that they are equally anonymous.

There is at stake here not only the question of artistic integrity (eight hundred years of habituation to the idea of the designer as individual are not easily swept away). A more basic question appears: Will the ultimate purpose of life on earth always include the opportunity for individual and social man to react creatively with his environment? Or is the behavior of an astronaut, confined in a capsule and subject to direction from a computerized control center, to be the model for our future existence on an overcrowded and oversystematized planet?

Doubts such as these impel those who have them to turn away from involvement in the processes of design and construction and to take up the study of how men use the space around them. From today's perspective it does indeed seem strange that no serious attention has ever been paid to this question. Institutions and their inherited trial-and-error patterns of space occupancy have hitherto been accepted without any serious challenge.

We now find this field to be the great nascent opportunity for architects. But years of exploration will be required to discover the appropriate questions and to develop true ways of observing and evaluating.

This architectural dichotomy, a pursuit on the one hand of complex systems for the beauty of their organization and process, and on the other hand an obsession with the significance of the individual human gesture that impacts the environment, is warring in the mind of every young designer today. Who can foretell now what resolution will come?

LAWRENCE B. ANDERSON

### **DEPARTMENT OF ARCHITECTURE**

Last year I reported that the interests of the Department were forming around a number of themes. They were: attention to the interaction between patterns of use and the spaces defined by building form; accumulation of a better base for design information and the evolution of computer-

aided design; development of building systems appropriate to the evolving conditions of the construction industry; means for extending design and technical assistance to members of society who previously have been isolated from decision about environment; urban design that accommodates the complex conditions of urban development; commitment to demonstration of new patterns for the local physical environment; exploration of the expressive potential inherent within current technical development. These subject commitments are generally still descriptive of our concerns.

In this report I should like to comment on some changes in the way the Department behaves. These changes have come about in response to a number of factors and through increased attention by all members of the Department to the societal conditions that surround us, especially the responsibility for maintaining a critical attitude toward those conditions. We have been guided, further, by a conviction that effective education must provide each student with responsibility for differentiating his particular interests within the educational resources established by the Department. Finally, we are developing a growing respect for the usefulness of concrete example, for the educational benefits of direct experience and of the research context in changing educational patterns.

At the beginning of the fall term, a student-faculty committee proposed — and the faculty approved — the development of patterns for project study based on individual student initiative. These are now an allowable substitute for faculty-defined architectural design projects. Students undertaking such study are charged with gaining the commitment of a faculty advisor to work with them and with defining a plan and schedule of study that would meet the approval of a faculty committee.

The projects undertaken in this way were varied. Several were close in nature to present professional practice. A larger number reflected student concern for deficiencies in the models presently used to guide environmental development — especially in housing and school building. The intention of these students was to find means for making these categories of building more responsive to local conditions and to the specific needs and preferences of their users.

Students who worked within the traditional design class framework were able to choose from several options. In the case of the revised graduate urban design program under Professors John R. Myer and William L. Porter, students contributed extensively to the formulation of the program, which had two clusters — one concerned with development of zoning guidelines for Massachusetts Avenue, the other with development of an advocacy role for a group of South End residents. Both projects have continued into the summer with sponsorship.

To allow time for differentiation in study patterns was one of the principal reasons for extending the Master of Architecture program by adding a two-year residency requirement. This, the first year of that plan, shows signs that it is a fruitful one. Students in urban design, for instance, have had time to study more deeply in supportive subject areas and to take advantage of a number of research opportunities. Students working with Professor Horacio Caminos have been able to spend time in South America this summer and will bring back to the program valuable research data.

For students working toward their first degree who find that their interests do not fit within the established professional curricula, we have provided an additional study option in the Bachelor of Science degree without specification. The Department will offer this degree to students who gain approval for a well-organized and purposeful program that, while based in the Department of Architecture, does not fall within the present curricular patterns.

These efforts to develop a more responsive educational pattern have not been without their toll. Strains measured in time, patience, and distraction have often made us look with nostalgia to the conveniences of rigorous packaging. Students and faculty alike are apprehensive lest we lose our community of interest and our ability to concentrate resources in the pursuit of excellence. Yet we remain convinced that valid education cannot be dominated by arbitrary restrictions. Conversely, these factors have contributed to an increasing self-consciousness in our efforts to understand the Department as a complex community of persons concerned with their mutual conduct. The most formal expression of this has been the initiation of monthly student-faculty luncheons. These have become a valuable forum for discussion of some of our most fundamental concerns. In addition, student-faculty study groups have contributed to a number of specific areas: the independent study program, revision in our consideration of curricula in environmental control, allocation of funds within the group for research in environmental design, the selections of projects, and the designation of a critic for the fifth-year subject, Architectural Design.

Divergence of activity has been amplified by the fragmentation of our location. Department subjects are presently being offered in four separate buildings. Considering the Webster Building as a possible new home for the School has given us the opportunity to examine in open forum a number of factors that describe our future. Several all-day, all-School meetings were held during the spring and a group consisting of Dean Lawrence B. Anderson, Professor Myer, and Professor Maurice K. Smith is conducting exploratory studies with a staff of seven students this sum-



mer under the sponsorship of the Planning Office. We expect that proposals developed this summer will serve as the base for further articulation of our community of interests during an extensive round of discussions to be held in the fall.

Extending from the Institute's commitment to Agenda Days this spring, we have asked a group of faculty and students to form an Arrangements Committee for the coming year, charged with continuing attention to a calendar that would encompass and give coherence to the full range of lectures, meetings, discussions and informal gatherings that are necessary to nourish a viable sense of community. Our concern for understanding the Department as a form of community is, of course, not independent of the increasing commitment within architecture to neighborhood action and to the development of patterns for user involvement in the design of the environment.

The past year has also seen a significant increase in the interaction between teaching and research. Support for research initiation that has been available to faculty through the Urban Systems Laboratory, the Ford Foundation grant, and the Sloan Basic Research Fund has made it possible for a number of projects to be developed that have served either directly or indirectly as the context for student projects.

The Community Projects Laboratory, under the direction of a faculty committee chaired by Professor Myer, has offered support and follow-up to several neighborhood projects involving students and to a group of faculty projects that attempt to gain a better understanding of the context in which architects and planners can contribute most effectively to community development. This summer Professor Robert Goodman is completing a study of changing roles within the design professions. Professor Chester L. Sprague has developed extensive contact with American Indian communities and their problems. Several specific Indian housing development projects, undertaken by his group, have served as the subject for student design projects. The work of Professor Stephen M. Carr of the Department of City and Regional Planning in surveying the present state of advocacy projects throughout the country has been an important component of the Community Projects Laboratory's activity, and the information that his group has collected will be important to further development in this area. Community Projects Laboratory funds this year have come from the Ford Foundation through the Urban Systems Laboratory, and from the National Endowment for the Arts.

Throughout this work runs the conviction that present institutional and professional arrangements are seriously inadequate to meet the problems of providing for elements of the community that have been disenfranchised and who often have needs and aspirations radically different

from those most easily assumed by designers and policy makers. These studies point to the need for extensive restructuring in systems for production of housing and in design of communities, if residents are to live in satisfactory relation to their immediate environment.

Continuing study, by a group associated with Professor Caminos, of self-help housing development in South America, was extended this year by cooperation with the Organization for Social and Technical Innovation (OSTI) in an evaluation study of self-help housing in the United States. John F. C. Turner, on leave from the Department of City and Regional Planning, coordinated the study for OSTI and Professor John A. Steffian directed the efforts of several graduate students attached to the study. We look to the emergence within the Department of a new combination of interests in the areas of user involvement in the production of housing.

The Architecture Machine is a phantom in the minds of Professors Leon B. Groisser and Nicholas P. Negroponete that is becoming concrete with disconcerting haste. Supported by the Urban Systems Laboratory and spurred by the vision of artificial intelligence, Professors Groisser and Negroponete have captured the attention of a number of energetic students and consultants. During the year the combined efforts of their research group and their class in Computer-Aided Urban Design have brought them a long way from the constraints of URBAN 5, their last system, even if they are yet below the horizon of a machine that can see, converse, and design in the manner to which they aspire. Their work has brought to the Department this year the gift of an Interdata computer, that, besides assisting their development schemes, can bring many more members of the Department into operating contact with computer capabilities.

Timothy E. Johnson's continuing studies in space allocation under National Science Foundation (NSF) sponsorship and the work that Professor Porter has been conducting with Professor Aaron Fleisher in the Department of City and Regional Planning fill out a picture of rapidly evolving research competence in the use of computers to assist with design, and we expect now to draw more on this in our teaching program.

The Urban Systems Laboratory also gave support during this year to a continuation of Professor Edward B. Allen's study of interchange facilities for a v/STOL (Vertical Short Takeoff and Landing) aircraft system. Conducted in cooperation with the Department of Aeronautics and Astronautics, the project involved two students directly and served as a study context for the design projects of a number of others who examined aspects of the problem or extensions of the ideas that would not have been feasible within the boundaries of the sponsored research.

Also with Urban Systems Laboratory support, Professors Smith and Waclaw P. Zalewski have each undertaken research initiation studies this spring that have directly established a context for continuing student work in the exploration of various problems of form definition. The group for research in environmental design, chaired by Professor Porter, made a small amount of money available for the direct support of student research projects.

For all that, students in the Department are yet builders, and perhaps the most compelling event of the year was the construction of an exhibit in the Hayden Gallery. "Form and Use in Architecture" was prepared under the direction of Professor Stanford Anderson as the product of a seminar, Theory of Architecture. Illustrating buildings and artifacts in which form and use have been mutually modifying, the exhibit consisted of multiple projection screens entwined by a mezzanine platform and a structure of plastic beams. More polished than the drafting-room mezzanines, to which they were related as a demonstration of multi-leveled and closely defined open spaces, the forms of the exhibit were yet challenging enough to perplex a group of architects who attended a two-day meeting of the Conference of Architects for the Study of Environment. The group was convened to discuss and criticize the exhibit and the theoretical positions illustrated, as well as to present their current work in public forum.

An Environmental Workshop was initiated this year as an elective subject open to all students at the Institute. Conceived in response to student interest, the Workshop was conducted by Hans H. Harms with an advisory group that included Dr. Benson R. Snyder, Chief of Psychiatry, myself, William H. Combs of Physical Plant, and Peter T. Van Aken of the Planning Office. Each contributed extensively to the subject, which enrolled 27 students during the year, about half from the Department of Architecture. The purpose of the subject was to encourage students to take initiative in giving consideration to their immediate environment and to use that initiative as a base from which to explore system ramifications in terms of procedures for change, multiplicity of reaction, and the difficulties and challenge of measuring response in a way that would be useful to future decisions. Several projects were undertaken during the year, without a high incidence of completion. Modification of the old Bursar's Office to a space open for informal student use was the major consequence of the Workshop. Several other projects have attracted interest, and there seems to be considerable evidence that there is widespread urge for reform in the quality of our public spaces.

The subjects in photography, visual design, and history of art have not been adequately reported in this summary. Many of the characteristic

changes in Department behavior, of course, include students in those subjects. For instance, several working with Professor Gyorgy Kepes were closely involved with continuing projects at the Center for Advanced Visual Studies in a manner similar to research-based study. It has been gratifying to have the Center bring advanced work in visual design to the Institute, so that there is visible extension of the undergraduate subjects in visual design offered by Professors Robert O. Preusser and Richard Filipowski.

The photography program continues to draw many students. Under Professor Minor White's leadership it has become an extraordinarily effective means for students at the Institute to become familiar with the ways in which configurations, gestures, and patterns of light can become a disciplined means for expressing something about one's view of the world.

This winter an exploratory program in film was initiated in cooperation with the Department of Humanities. Edward Pincus joined our faculty as Lecturer to organize and teach an introductory subject in film making which enrolled 18 students, four from the Department. Limits of space and available funds forced us to turn away many applicants. The subject was concerned mainly with bringing students to understand the ways in which film as a medium can be used to explore and comment on aspects of the social and physical environment. Students produced a number of short but impressive films, and we look forward to the opportunity to expand this program.

A seminar, New England Architecture, conducted by Professor Henry A. Millon, benefited from extended and fruitful visits to towns throughout the region. Initial probes into the original source materials for New England town development confirm our commitment to the early development within the Department of subjects in the history of urban form as an extension of the already distinguished offerings in history, theory, and criticism of the arts and architecture. We hope soon to be able to offer a doctoral program in these areas.

#### FACULTY CHANGES

A number of visitors contributed importantly to the program of the Department this year. Julian Beinart, Head of the Department of Urban and Regional Planning, University of Cape Town, South Africa, was Bemis Visiting Professor during the spring term. It was a special pleasure to have him with us; he entered easily into the full life of the School. He and his students conducted a study of future growth possibilities and constraints in the vicinity of the M.I.T. campus — a study for which his particular combination of planning background and social commitment was particularly germane.

Giancarlo De Carlo of Milan again visited the School in the fall and in the spring for three weeks each. Professor De Carlo's visits have proven to be very stimulating for the Department. He addresses issues of planning and form with uncommon directness and brings an important perspective to the work going on in the School.

Laurence S. Cutler served this year as Visiting Assistant Professor on leave from the Rhode Island School of Design. He joined Professor Albert G. H. Dietz in conducting a design studio and seminar concerned with industrialized housing.

Albert Bush-Brown, former colleague and until recently President of the Rhode Island School of Design, gave generously of his heavily committed time to conduct a seminar during the fall term concerned with the urban form implications of various Federal programs.

New members of the faculty were quick to assume significant responsibility in our evolution. Richard C. Tremaglio, who joined us as an instructor after completing his Bachelor of Architecture degree here, has been especially stimulating and helpful. Jonathan W. Green, Instructor in photography, also served with an exceptional sense of responsibility. Mr. Harms and Mr. Pincus have been mentioned before. William L. Porter, who was appointed as Assistant Professor in architecture and in city and regional planning, has certainly carried full-time responsibility for us, and one suspects that he must either be two people or derelict in his duties to our fellow departments. In addition to playing a strong role in the Community Projects Laboratory, and in co-authoring the new urban design program, Professor Porter has more than shared my duties as Associate Director of the Urban Systems Laboratory.

Chester L. Sprague became Associate Professor this year. Leon B. Groisser, Nicholas P. Negroponte, Patrick Morreau, and John A. Steffian were each reappointed Assistant Professors. Professor Eduardo F. Catalano was absent on leave for the year, Professor William H. Brown for the fall term, and Professor Caminos for the spring term. Professor Jan Lubicz-Nycz has resigned after three years of teaching in the graduate program. We have been grateful for his contribution. Professor William J. LeMessurier has withdrawn from the faculty to commit himself full-time to his very successful engineering practice.

In conclusion, I should like to note especially the importance of Professor Millon's contribution to the faculty this year. As a member of the Committee on Educational Policy he has, like his colleagues on that body, given extraordinarily of his time and energy, not just to their deliberations, but to keeping the rest of us in the Department alert and informed. He has, in addition, joined with Professors Myer, Sprague, Porter, Dietz, Stanford Anderson, and Dean Anderson in a departmental

advisory group on which I have relied heavily. Professor Millon has also been chairman of the film study group. These would not, perhaps, be such extraordinary contributions if he did not also continue to attract the highest respect and enthusiasm of our students.

#### ENROLLMENT

The Department is still in transition from a five-year undergraduate program to a six-year sequence with a Bachelor of Science in Art and Design (B.S.A.D.) at four years and the first professional degree, Bachelor of Architecture (B.Arch.), after two years of graduate study. A few students completing the old program are still in course, while those in the new program are now the majority.

In 1967-68 there were 52 undergraduate candidates for the B. Arch.; in 1968-69 this number was 23. Candidates for the B.S.A.D. increased from 30 to 71, while the enrollment of graduate student candidates for the B. Arch. increased from 37 to 44. Candidates for the M. Arch. degree decreased to 22, since this year we admitted fewer candidates in light of the new two-year residency requirement. The corresponding number in 1967-68 was 35. Special Students numbered 26, compared with 29 in 1967-68. Of special interest was the significant increase in undergraduate interest in the following second-year subjects: 4.121, Architectural Design, in which enrollment increased from 26 in 1967-68 to 40 in 1968-69; and 4.30, Structures I, in which enrollment increased from 31 in 1967-68 to 59 in 1968-69. This increase may forewarn of a future increase in the enrollment of undergraduate degree candidates in the Department.

During the year the following degrees were awarded: B.S.A.D., 8; B. Arch., 20; and M. Arch., 35.

DONLYN LYNDON

#### DEPARTMENT OF CITY AND REGIONAL PLANNING

A significant step will be taken when the name of the Department of City and Regional Planning will be changed to the Department of Urban Studies and Planning. The new name reflects the radical transformation which is gradually taking place in the focus, direction, and scope of the teaching and research activities of the Department, as set forth in our recent annual reports.

The changes taking place involve not only the subject matter and methodology of the planning profession, but its basic horizons. The change has been sparked in large measure by the ever deepening crisis of our urban centers, and by the increasing involvement of both faculty and

students in seeking solutions to the interlocking social, physical, and economic problems of which that crisis is compounded. As a result, the traditional emphasis on the manipulation of the physical environment has shifted to a wider concern for the human interaction with that environment, and a search for strategies to guide purposeful change in social and psychological relationships, in economic development, as well as — and in conjunction with — environmental development and redevelopment.

Specifically, the Department is seeking to expand the capacity of planners to cope with a spectrum of environmental issues: race, poverty, migration, education, health, conservation, economic growth, and the means by which individuals in the system can participate in the public decisions which affect their lives. We are also seeking first-hand knowledge of how people perceive and use their environment, and how it affects their mobility — both their physical mobility within the city, and their mobility in the social and economic sphere.

Further, the Department is increasingly concerned with the need for the development of policies and strategies to guide urban growth, which will lessen the growing gap between thriving areas and depressed ones, between urban pockets of poverty and suburban affluence. The establishment of national goals, priorities, and policies to effect changes in growth patterns, both in this country and in developing countries, is an important part of the Department's program.

These evolving and intensifying efforts place specific emphasis on the analyses of complex, dynamic systems of varying scale. They mean that, rather than dealing with one set of values in planning, we must consider the diverse values of a plural society, at the scale of neighborhood, community, city, region, and nation.

To accomplish this kind of revolution in the field of planning, and to build from where we are now, the Department has many needs. A new base of knowledge must be established through a new level of research; the educational curricula must be revised and expanded; new tools for the analysis and manipulation of data must be utilized. For these purposes the already multidisciplinary faculty of the Department must be strengthened and enlarged by bringing in participants from other fields as well as reorienting those already centrally engaged. New technological tools and equipment must be obtained; more space must be found to accommodate an enlarged student body and faculty. More research opportunities must be provided.

#### STUDENTS

The students entering our graduate programs are themselves an element in these changes — their interests, their drive, their concerns and com-

mitments, and their quality. They continue to be drawn from a wide variety of backgrounds, many with some years of experience or with prior advanced degrees in other fields. Nearly half the total are doctoral candidates; the others are in the two-year professional Master of City Planning (M.C.P.) program. Increasingly, they are a highly selected group. Those entering in September, 1968, were one-tenth of those who applied, while the ratio for September, 1969, will be one-twelfth. Last year two degree candidates (out of about 80) were Afro-American; this coming year, there will be seven out of about 90.

Like their fellows in other departments and other universities, our students seek responsible participation in the shaping of their "now" lives — their academic environment — as well as preparation for future responsible participation in shaping their society. Last year they sparked an overdue revision of the M.C.P. curriculum. This year, with faculty encouragement, they have become involved in many other aspects of the Department's operations and governance.

Without the formalities of a "student organization" and a cumbersome constitutional structure, a number of "task forces" have come into being. Each consists of a handful of students plus one or more faculty members intensely concerned with some topic related to departmental development and change.

One of these task forces, concerned with the twin issues of new faculty and new Course work, has explored many possible additions to the teaching staff and the new Course work that would come with each addition. It has interviewed many prospects, and has influenced constructively the Department's decision to offer appointments (or not) to new junior and senior staff.

Other task forces have devoted great time and attention to two matters discussed later in this report: research and student involvement in research, and the projected undergraduate program in urban studies.

One group has worked to devise means of formalizing a structure for sharing with students the decision making that controls the Department's operation and change. No consensus has emerged as yet. Nevertheless, it seems desirable to continue to seek more effective ways of structuring this and other departments — including perhaps restructuring of the university itself.

#### FACULTY

Additions to the teaching staff for 1968-69 reflect the multidisciplinary trend of the Department. Associate Professor Robert M. Fogelson, urban historian, holds a joint appointment with the Department of Humanities. Assistant Professor William L. Porter, urban designer, was jointly ap-



pointed with the Department of Architecture. Visiting Professor Frank I. Michelman, of the Harvard Law School faculty, came to teach our urban law subject. Visiting Professor Jean Paelinck, here for one year from the Faculté des Sciences Economiques et Sociales, Namur, Belgium, was shared with the Joint Center for Urban Studies and with the Department of Economics. Senior Lecturer Morris Axelrod, heading the Joint Center's Boston Social Survey Project, was shared with the Sloan School of Management and the Department of Political Science. Lecturer Robert S. Weiss taught a social science research methods subject. Instructor Gail B. Hall taught our urban sociology subject.

The enrichment made possible by these shared and part-time appointments was costly in that too few full-time departmental faculty were available to advise and counsel students, an increasingly necessary function with the new flexibility of our Master's program. This coming year further additions will, we hope, correct this balance.

New appointments entirely within the Department include Professor Herbert J. Gans, who will teach sociology and planning, a distinguished addition to our growing specialization in social policy planning. Ralph A. Gakenheimer, Visiting Associate Professor from the University of North Carolina, has worked the last two years in Chile and will strengthen our developing-countries offerings, as well as general planning. Assistant Professor Ronald A. Walter, recent Ph.D. from M.I.T.'s Department of Civil Engineering, will work in transportation and urban information systems.

Of last year's new additions, all will continue except Professor Paelinck, whose place will be taken by Senior Lecturer Christopher D. Foster, for the past three years Deputy Minister of the British Ministry of Transport in charge of transportation research. His time will be shared by the Joint Center and the Department of Economics.

During the last year, Dr. Lisa R. Peattie, Lecturer in Anthropology, was promoted to Associate Professor. At the end of the year Associate Professors Aaron Fleisher and Bernard J. Frieden were promoted to Professor.

#### UNDERGRADUATE PROGRAM

The Department has proposed to offer a new undergraduate program, leading to the degree S.B. in Urban Studies. Though not yet approved by the M.I.T. Faculty and the Corporation, we hope it will be authorized to begin in September, 1970.

The proposal has been the object of intensive study by one of the student-faculty task forces, which has worked not only on the form and content of the program but also on how to make it an asset to the graduate program, and how to make the transition for undergraduates changing

from other fields. Several advanced students have part-time staff appointments this summer and next year, playing major roles in developing two new undergraduate subjects central to the proposed curriculum, to be tried out in the coming year.

This program will be designed for students who wish to pursue careers related to city problems, but whose interests are not comprised in any of the present S.B. programs. We see four main objectives:

1. Urban studies can serve as the base for an excellent interdisciplinary technical education. It can provide a program and content for integrating sciences and technologies in the exploration of a single problem area. The program would enable the student with a technical background based on the General Institute Requirements to see the applications and impacts of related disciplines in a social setting.
2. Although the proposed program is not professional or preprofessional, the kind of education proposed would be an entree into immediate employment in many kinds of jobs. At the same time the interdisciplinary orientation of the program, combined with M.I.T.'s stress on analytical skills and technical competence, would prove attractive to graduate schools in a wide range of fields, as well as to our own graduate program.
3. There is substantial and growing student demand within M.I.T. and elsewhere for exactly this kind of program. Increasing numbers of undergraduates are committed to work on urban problems, but want to find out first about the city as a phenomenon and the various ways of dealing with it, before choosing a professional or career specialization.
4. An undergraduate program in our Department will bring important benefits to our program in many ways. Some increase in enrollment will bring a larger faculty, with greater richness and flexibility. There will be valuable opportunities for graduate students to gain teaching experience and share in subject development. There will be a base for continuous curricular innovation, which can feed both up to and down from graduate subject work. We will also be in a better position to relieve some of our graduate subject work of the presence of many undergraduates, and enable its upgrading. (This past year, one-fourth of all the subject registrants in this Department were undergraduates.) There will be opportunities to develop new and stronger ties to other departments, which are increasingly important to us. Finally, we will create a new kind of candidate for our advanced degrees, technically based and seriously needed.

#### RESEARCH

The Department's research within our Laboratory for Environmental Studies has continued to expand, with a dollar-volume of sponsored research roughly twice that of the previous year. The range of work re-

ported a year ago has continued. The single major project has been under a grant from the Economic Development Administration to study economic problems of urban ghettos, and has involved faculty from the Departments of Economics and Political Science as well as many of our own.

A new move has been the product of another of the student-faculty task forces, devoted to developing opportunities for student research, not merely as assistants in some faculty member's project but as investigators on projects of their own initiation. This has been encouraged by the Urban Systems Laboratory, which has funded two unique experiments this summer. One is employing a group of students from several disciplines to explore new ways by which an outer suburban town — specifically Northborough — can control its growth and improve the quality of its development; the town is also helping finance this project. The other is a block grant administered by another group of students to finance individual research efforts, in several cases exploring potential thesis projects.

The general goal of the Department's research program — a familiar goal, but especially relevant in this under-researched field of urban problems — is to fuse research and teaching, combining the discovery of new and useful knowledge about cities with the development of effective professionals and teachers in our field.

#### **SPURS**

The Special Program for Urban and Regional Studies for Developing Areas (SPURS), under Professor Lloyd Rodwin, has completed a second year with about a dozen mid-career professionals from Latin America, Asia, and Africa. It has received a substantial grant from the Ford Foundation which makes it possible, starting this coming year, to provide fellowships and travel grants to a number of promising participants who could not otherwise attend.

#### **PROSPECTS**

The Department has been encouraged and enabled to grow rapidly, in enrollment, faculty, subjects, research, and in floor space, by an M.I.T. administration sympathetic to our purposes and cognizant of our potential share in M.I.T.'s response to the problems of an urban civilization.

In proportion to those problems, we are still small and still inadequate. We hope for further growth, in numbers, in capability, and in quality. We realize that such growth requires major new financial resources, and have submitted to the administration our proposals for the funding needed. We are confident of help and hopeful of success.

JOHN T. HOWARD



## SCHOOL OF ENGINEERING

**T**he word "relevance" has received at least as much attention recently as any of the other terms used to describe the objectives of educational reformists. But those who cry the loudest for a greater relevance of education to society's problems are rarely from the schools of engineering, for this is what engineering is all about. An engineering school not tuned to the current needs of society fails to fulfill its function.

Since the emergence of formal engineering education during the latter part of the nineteenth century, an increasingly important role has developed for the engineer in the solution of the problems of society. He provides a bridge between the needs of society and the laws of nature. William Barton Rogers expressed this thought in different words when he enunciated his plan for the "improvement of industry and agriculture by a knowledge of its connection with truths and laws." However it may be phrased, this vision is as clear now as it was in Rogers' day; our problem is not to find a new vision but rather to implement the old one within today's environment. The last century has seen vast changes in the needs of society and also in the rate at which these needs change. Our understanding of the laws of nature has also changed in detail and at a rate not unlike that at which social needs change. Thus, the engineer faces the problem of building bridges between banks that shift at ever-increasing rates.

One of the clearest needs of society is the creation of an environment in which man can work and live. During most of the history of his profession, the engineer has devoted his efforts toward overcoming the environmental problems posed by nature. These are still important problems and are exemplified in the modern world by the design of a space capsule or of an undersea submersible.

But today we face new, man-made environmental problems with which the engineer is only beginning to grapple. The activities of the School of Engineering, during the past year, were characterized primarily by a growing concern for human and societal problems in contrast to the heavy engagement of earlier years in the narrow, sophisticated problems posed by the nation's military and space programs.

#### **GROWING CONCERN FOR MAN-MADE ENVIRONMENTAL PROBLEMS**

Improved energy sources, environmental pollution, transportation, the interactions between engineering and living systems, and urban systems are examples of areas receiving increased attention in the education and research programs of the School of Engineering during the past year.

Mankind's success in changing and improving his environment has always been dependent upon his ability to exert control over energy and matter. Nuclear energy continues to offer bright promises as the major future source of energy for the expanding world population. Provision of this energy is the central focus of the activities of the Department of Nuclear Engineering, which emphasizes two major unifying themes in its research and instruction programs: fission reactor technology, and applied plasma physics. Most experts agree that the future of each of these fields is bright indeed and that the nuclear industry will grow steadily. The outlook for fusion power reactors has improved during the past year. Improvements in both confinement time and estimates of the energy removal system from a well-confined thermonuclear plasma have resulted in more optimistic views about the feasibility of a controlled fusion machine.

An important factor in the development of the educational program in the Department of Metallurgy and Materials Science has been the role of the Student Metallurgical Society. In response to opinions about the curriculum expressed by this student group, an ad hoc committee chaired by Professor Morris Cohen, with membership drawn from younger faculty members and the student body, has been formed to give education in materials science, and the present curriculum, an extensive review. This activity, together with a thorough examination by graduate students and faculty of the requirements for advanced degrees, has served to improve the educational program of the Department. Perhaps the most significant current addition to the offerings of the Department, however, does not primarily concern its own students. During the year, Professor John Wulff introduced a new freshman subject, 3.091, Introduction to Chemistry of the Solid State. This subject, which has been adopted by the Faculty as one of the five alternatives that may be used to satisfy the undergraduate

chemistry requirement, was taught during each term and attracted a total of almost three hundred students.

The Departments of Mechanical, Chemical, and Civil Engineering, Aeronautics and Astronautics, and Naval Architecture and Marine Engineering have become increasingly involved in the problems of environmental pollution. These activities include strong and growing programs related to the dispersion of atmospheric pollutants from stacks and ground sources, the formation of pollutants in internal combustion engines, the collection and disposal of the solid wastes and trash in urban areas, the desalination of water, the containment and collection of large oil spills in offshore waters, and aircraft noise. The experience of the past year has brought sharply into focus the fact that entry into these fields poses extremely difficult problems of financial support. For military and space research, funding has been relatively easy to obtain for the past decade, and the Federal agencies involved have considerable experience with the administration of research programs with universities. For environmental problems, however, the monies available are small and the agencies involved lack experience with university research methods and policies. It is clear that the determination of M.I.T. students and faculty to work in the field of environmental pollution is very high indeed, and their potential contributions will be considerable, provided financial support can be found. However, the support obtained so far has required arduous efforts and sacrifices by our faculty, together with a large measure of M.I.T. internal funding.

The year 1968-69 saw increasing involvement in the field of mass transportation within the School of Engineering. The Department of Aeronautics and Astronautics continued its trend toward emphasis on commercial air transportation spanning the range from short-haul V/STOL (Vertical Short Takeoff and Landing) aircraft to the hypersonic transport, in contrast with its earlier heavy involvement with military aircraft, space vehicles, and missiles. Of fundamental importance to the future of the Department is the realization by its faculty that it is no longer possible to consider a flight vehicle in isolation. The total requirements, including its economics, the community it serves, and its impact on the environment in which it operates, must be taken into consideration in such a way as to produce an optimum system. For this reason, the Department has continued to emphasize project-type subjects in which systems are developed and analyzed either collectively by the class or by students individually.

The Department of Naval Architecture and Marine Engineering completed its 75th year of operation this year, having been established as an independent department in 1893. The Department considered it appro-

priate during this anniversary year to concentrate its efforts on planning an educational program directed at the foreseeable challenges of the next decade; a program which aims at developing in each student a basic knowledge of the engineering sciences as well as the capability for imaginative application of engineering principles to the ocean environment.

In transportation, the involvement of the Departments of Electrical, Civil, and Mechanical Engineering grew in scope and importance during the year. Dual-mode guideway research under the direction of Professors William W. Seifert and Dwight M. B. Baumann is an example of a current program of joint interest to the three departments. A 200-foot test track was completed, and a prototype automobile was operated under passive steering control referred to a mechanical guidance rail. This experimental system attempts to combine the flexibility of a personal vehicle with the control and channel capacity of an automated transit system to achieve optimum door-to-door travel convenience.

A substantial number of the students and faculty of the Departments of Mechanical, Electrical, and Chemical Engineering and Aeronautics and Astronautics, with smaller numbers from the Departments of Metallurgy and Materials Science and Nuclear Engineering are now engaged to some degree in research in the general area of engineering and living systems. Of the total efforts of the School, the fraction which are directed toward these ends is increasing rapidly. For example, one-fourth of the faculty of the Department of Mechanical Engineering is engaged to some extent in medical research problems. The contributions of the School of Engineering in this area are impressively illustrated by the work of Professor Robert W. Mann of the Department of Mechanical Engineering; he is applying engineering principles to the rehabilitation of humans with major sensory and muscular-skeletal deficiencies. The proportional-rate, force sensing, electromyographically controlled artificial elbow that resulted from M.I.T.'s collaboration with the Harvard Medical School, the Massachusetts General Hospital (M.G.H.), and the Liberty Mutual Insurance Company was presented at a press conference at M.G.H. and promptly became known as "the Boston Arm." The use of this battery-powered limb is being extended to clinical field evaluation at four orthopedic and prosthetic clinics along the eastern seaboard.

Although involvement in urban affairs extended to some degree across all departments, the focus of these activities for the School has centered in the Urban Systems Laboratory and the Department of Civil Engineering. While faculty and students from many departments of the Institute participated in the work of the Laboratory, the Department of Civil Engineering, under the leadership of Professor Charles L. Miller, played the leading role in establishing this new Institute-wide activity and in develop-



#### SCHOOL OF ENGINEERING

ing its program. During the year, more than half of the faculty and students of the Department of Civil Engineering participated to some extent in the activities of the Laboratory. Its largest project, under the direction of Professor Daniel Roos, relates to the field of urban mass transportation. This project, which involves more than 70 faculty, students, and professional staff, is sponsored by the Urban Mass Transportation Administration of the U. S. Department of Transportation and is focused on the development of a new dynamic computer-controlled public transportation system.

#### ADVANCED ENGINEERING STUDY

The activities of the Center for Advanced Engineering Study grew in scope and size during the year. Perhaps the most significant event was the dedication in October, 1968, of the new building of the Center with its faculty and student offices, seminar and classrooms, 170-seat auditorium, high-speed digital computer laboratory, and completely equipped television tape production facility.

#### INFORMATION TRANSFER ENGINEERING

No summary of the activities of the School would be complete without mention of Project INTREX, now in its fourth year of operation. The Project's work continues to be guided by its original goals of finding long-term solutions for the operational problems of large libraries and of developing competence in the emerging field of information transfer engineering. Indicative of progress during the past year was the decision by the National Science Foundation and the Council on Library Resources to continue their financial support.

#### ENROLLMENT TRENDS IN ENGINEERING AT M.I.T.

The trend of enrollment in the School during the past year followed approximately that of M.I.T. as a whole. There was a reduction in the graduate enrollment of 4 per cent and an increase in the undergraduate enrollment of slightly more than 1 per cent. The overall undergraduate enrollment in the School has remained essentially unchanged during the past eight years, whereas the graduate enrollment is some 17 per cent greater than it was in 1960-61.

There is, however, in entering undergraduate student interest at M.I.T., a trend of vital importance to the School. While 67 percent of the entering students of the class of 1958 stated a preference for engineering, only 31 per cent of the entering students in the class of 1968 showed a similar preference. On the other hand, 22 per cent of the entering class of 1958 and 52 per cent of the entering class of 1968 stated a preference for

science. These figures indicate clearly that science has displaced engineering as the dominant interest of entering freshmen at M.I.T. During the same period, however, a major increase in interest in engineering was noted between the time of application and the time of graduation. In fact, this increase was such that 48 per cent of the class of 1968 finally graduated with degrees from the School of Engineering, while 34 per cent graduated with degrees in science. Thus, for the class of 1968, an original preference of 31 per cent for engineering grew to 48 per cent, and an original preference of 52 per cent for science declined to 34 per cent between the time of application and the time of graduation.

#### PERSONNEL HIGHLIGHTS

Since the submission of the last report of the School of Engineering, Professor Gordon S. Brown, who had served as Dean of the School since 1958, stepped down to accept a new chair, the Dugald C. Jackson Professorship in Engineering. In addition, Professor William W. Seifert resigned his position as Assistant Dean in order that he might devote his full attention to teaching and research. In addition to resuming his post as Professor of Electrical Engineering, Professor Seifert was appointed Professor of Engineering in the Department of Civil Engineering. The entire School is indebted to Deans Brown and Seifert for their leadership of our activities during the past decade. They have assured the School a preeminent position in engineering education. On November 1, 1968, Professor Raymond L. Bisplinghoff was appointed Dean of the School of Engineering and on July 1, 1968, Robert H. Scott was appointed Assistant Dean for Administration.

Professor René H. Miller, H. N. Slater Professor of Flight Transportation, was appointed Head of the Department of Aeronautics and Astronautics, effective November 1, 1968, succeeding Professor Bisplinghoff.

During the year, Professor Edwin R. Gilliland asked to be relieved of his administrative duties after having served 12 of the last 18 years as Head of the Department of Chemical Engineering. In March, 1969, he became the first Warren K. Lewis Professor of Chemical Engineering and was succeeded as department head by Professor Raymond F. Baddour. The entire School of Engineering and, in particular, the Department of Chemical Engineering have benefited immensely from Professor Gilliland's leadership over the years.

Professor Elias P. Gyftopoulos served with distinction as Acting Head of the Department of Nuclear Engineering during the year, while Professor Manson Benedict was on sabbatical leave. Professor Benedict, who resumes his duties as department head on September 1, 1969, received the Atomic Energy Commission's citation for outstanding service in the

nation's atomic energy program, the Robert C. Wilson Award in Nuclear Chemical Engineering of the American Institute of Chemical Engineers, and the Arthur Holly Compton Award of the American Nuclear Society for contributions to nuclear engineering education. He has recently been appointed Institute Professor in recognition of his outstanding contributions to industry, government, and education.

Professor Theos J. Thompson of the Department of Nuclear Engineering requested a two-year leave of absence to accept an appointment as Atomic Energy Commissioner and Professor David J. Rose, also of that Department, was granted a two-year leave to join the Director's office at the Oak Ridge National Laboratory.

Professor Emeritus Samuel C. Collins received an honorary degree of Doctor of Law from St. Andrews University. During the past year he was elected to the National Academy of Sciences and also received the Gold Medal of the American Society of Mechanical Engineers, the highest award bestowed by that society.

Professor Emeritus Harold E. Edgerton received the John Oliver LaGorce Gold Medal from the National Geographic Society for his contributions to science and exploration. He also received honorary degrees from Doane College in Crete, Nebraska, and from the University of South Carolina.

During the year, in addition to Professor Collins, Professor Emeritus Egon Orowan and Professor J. C. R. Licklider were elected to membership in the National Academy of Sciences.

Three senior members of the School's faculty retired during the year. They are Thomas K. Sherwood, Lamot du Pont Professor of Chemical Engineering, a leader in his field who has made many outstanding contributions to chemical engineering; Yuk-Wing Lee, Professor of Electrical Engineering, one of the nation's pioneers in communication theory and an associate with the late Norbert Weiner; and Cyril S. Smith, Institute Professor and Professor of Metallurgy and Materials Science, one of the nation's most noted physical metallurgists.

RAYMOND L. BISPLINGHOFF

## **DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS**

This year has seen a continuation of the Department's efforts to insure that the undergraduate program remains a vital, fundamental education for the professional engineer, preparing him for a continuing learning process, whether on the job or in graduate school. To this end, several ex-

periments in undergraduate teaching are being conducted, as discussed below. Their intent is to instill in the student an appreciation for the full potential of his profession and the manner in which it interacts with, and serves, society.

In the graduate program, continuing effort to widen the basis for student support has had the result that almost 60 per cent of the support for on-campus research is now coming from civilian government agencies, in particular the National Aeronautics and Space Administration (NASA) and the Department of Transportation, as compared to some 30 per cent three years ago. The Department has continued to strengthen its ties with the Instrumentation Laboratory in order to take full advantage of the unique opportunity that this Laboratory presents to conduct meaningful research in support of graduate theses, and to observe at first hand the integration of complex systems.

#### THE UNDERGRADUATE SCHOOL

Enrollments in the second-, third-, and fourth-year classes were 59, 75, and 77, respectively, during the fall term, continuing the slight decline noticed last year. Bachelor of Science degrees were awarded to 64 students. Fifteen juniors in the Cooperative Course were at participating plants during the spring term. Elective subjects and seminars were presented to about 100 different freshmen during the year.

Under the leadership of Professor Walter McKay, the Undergraduate Committee continued its active role of stimulating improvements in curricula and counseling matters. It endorsed the retention of chemistry as a requirement, and deemed the pass-fail grading experiment for seniors successful at the level of one subject per term, but felt that it should not be extended. With students attending in response to open invitations, the Committee explored ways in which a sense of community among students could be enhanced, resulting in constructive suggestions for a student lounge, storage lockers, and for informal post-seminar dinners with guest speakers and faculty members. Students also expressed interest in strengthening the ties between academic subjects and professional practice.

During the fall, Professor Robert L. Halfman met with a group gathered by Professor George E. Valley of the Department of Physics to consider major innovations in freshman education. This led to the formation of the new Experimental Study Group for the summer and the next academic year.

Professor Halfman also developed an experimental version of the required undergraduate subject, Dynamics, 16.01, this spring. With the participation of Professor Eugene E. Covert and Fred J. Marcus, a group of

20 students agreed to study the regular subject matter largely at home on their own and in their own ways, but with the help of study guides on each of eight sections of the subject. It appears that they learned much of the material in a different way than usual. The students said they studied for comprehension rather than for developing skill in taking examinations. Considerable personal contact allowed the instructors to gain the impression that the students had a good grasp of the material, which unfortunately was not very apparent in the few formal written examinations. The experience was very attractive in many ways to both the teachers and most of the students. Yet it raises serious questions such as the difference between subjective and objective understanding, and motivation of the latter when the learning atmosphere is open and not highly structured.

Another experiment in undergraduate teaching was the Creative Engineering Symposium, conceived by Professor Yao T. Li with the help of Professors Walter M. Hollister and Louis L. Bucciarelli, designed to bring together students, industry, and faculty in a coordinated program of discussions and workshops stressing creative approaches to challenging engineering problems. There was hope that the students would learn more about real-world engineering in industry and that everyone would gain some insight into the creative process in engineering.

There were two major aspects to the program: formal presentations and student workshops. The formal presentations were given during the day from Thursday morning through Saturday noon, April 17 to 19, 1969. Department classes were canceled Thursday and Friday to permit greater attendance. Student workshops were held Wednesday afternoon, Wednesday evening, and Thursday evening. Students formed into groups, averaging four persons each, to work on problems submitted by participants from industry. About 25 problems were available to individual students three weeks prior to the Symposium, and the groups were formed one week prior to the Symposium. Written solutions were handed in Friday morning. The solutions were judged by industrial experts and cash prizes awarded to the winners on Saturday morning.

More than 50 representatives from industry registered for the Symposium, and approximately 130 students participated in the workshops.

A number of groups organized with representatives from industry went to dinner together and worked late into the evening. They also held similar sessions on Thursday evening. This part of the program received the most consistently favorable reaction from both students and industry. Following the Thursday evening workshops, most of the students worked into the early hours preparing their written solutions.

Twenty-eight papers were submitted for judging by the industrial ex-

perts. Ten of the papers were clearly superior in creativity and feasibility. The final judging selected five for cash prizes and named the other five for honorable mention. The committee had to judge systems problems against component problems and papers by graduate students against papers by sophomores and freshmen. Apparently, they could compensate for differences in age and experience of the authors much more easily than for differences in the breadth and interdisciplinary nature of the problems.

There was a banquet held in the Student Center on Friday evening, which attracted 180 people, including a fair number of wives and dates. On May 6, the prize-winning groups presented their solutions at a departmental seminar.

Those persons, who did attend the formal presentations, felt that they were very good, even though many of the papers failed to identify creative innovations as intended. There was extensive discussion following many of the papers, which was also judged to be very good. The students' primary gain came from their association with the industrial people through the workshops. They could talk openly, learn how their classroom principles apply to practical problems, and see the interrelationships of their different subjects. The informality of a group clustered around a blackboard in contrast to a formal presentation was praised. Students were surprised to find they could communicate with and be accepted as equals by industry. They demonstrated a willingness to work intensively for a solid week on a creative problem, something otherwise difficult to motivate. Although the nominal objective was increased creativeness among students, the major achievement was a better understanding of the interrelationships between topics taught in several subjects. There was also the realization on the part of students that it is more difficult to formulate a problem than to solve it.

The experiments in undergraduate teaching, symbolized by the two activities discussed above and by our continuing emphasis on the systems engineering subjects discussed below, are indicative of the Department's efforts to generate an environment in which the teaching of engineering and its scientific disciplines can continue to motivate creative young people.

Continuing undergraduate interest in aeronautics and astronautics stems from the challenge which this field has managed to maintain as it advances into new fields of technology, sometimes beyond the fringes of supporting scientific knowledge. This has placed major emphasis on the acquisition of the necessary mathematical and scientific tools in the undergraduate curriculum, to the point where much of the application and synthesis has had to be removed or deferred to the graduate year.

The Department thus faces two important questions which must be answered positively if growth and the quality of its graduates are to be maintained:

1. Will aeronautics and astronautics continue to challenge the bright young men of the future and, if so, along what paths?
2. Will we be able to maintain, particularly in our undergraduate curriculum, the necessary mix between theory and application while still providing the scientific tools that would permit our graduates to continue growing with their profession as it advances into new fields?

In answering the first question, the faculty of the Department anticipates some decline in popular interest in space activities, although it is unlikely that this pause will be of long duration. Applications for near-earth satellites, and the potentials of planetary explorations and deep space probes, are limited only by national budgetary considerations. These same considerations will require increased emphasis on methods for reducing mission costs. In particular, reusable launch vehicles will stimulate advances along the full spectrum of engineering, including structures, propulsion, guidance and control, and aerodynamics. These space transports may also bridge the gap between space and atmospheric flight, providing advanced capabilities for hypersonic air transportation. Similarly, interest in the supersonic transport will continue, again limited only by budgetary considerations. The superjets already in flight status will open new vistas in long-haul transportation. On the other end of the range spectrum, short-haul VTOL (Vertical Takeoff and Landing) aircraft operating from urban centers and taking advantage of the low costs, made possible by the productivity of high-speed aircraft, will almost certainly open up markets for air transportation that could dwarf the existing market, fast as it may be growing. In addition, such a short-haul inter- and intra-urban air transportation system could have a major impact on future urban planning, permitting greater decentralization and thereby contributing to the relief of many of our present urban ills.

The realization of these potentials of flight transportation in space and in the atmosphere will require the development of sophisticated techniques for analysis of complex systems. No longer is it possible to consider the vehicle alone. The total system, including its economics, the community it serves, and its impact on the environment in which it operates, must be taken into consideration in such a way as to optimize the total mission. The need to expose the student to the systems analysis approach provides this Department with one of the teaching mediums for insuring a positive answer to the second question, that of maintaining engineering awareness in students subjected to a great deal of necessary theory. For this reason, the Department has continued to put emphasis

on project-type subjects in which systems are developed and analyzed, either collectively by the class, as in Advanced Space Systems Engineering, 16.74, or individually, as in Flight Vehicle Engineering, 16.71, and Space Systems Engineering, 16.73. These subjects are supplemented by air transportation systems subjects, Flight Transportation, 16.751, and Flight Transportation Operations Analysis, 16.77, and a laboratory subject required of all students, Experimental Projects, 16.62.

The balance between theoretical analysis and engineering application, between learning and doing, the acquisition of information and training in the thought process of creative engineering, is difficult to maintain in a four-year sequence. However, in the aerospace sciences, specific knowledge tends to be perishable, and this Department has, therefore, leaned towards training in the sciences and exercises in their application rather than the cataloging of specific pieces of useful information on the state of the art as it may exist today. It is important to make clear to the student, at all times, the aim of this educational process, because the balance is so delicate, and frustration can easily develop. For this reason, a new subject is being organized by Professor Leon Trilling for the fall term of 1969, in which the practice of the profession, its responsibilities, aspirations, and distinguished history will be placed in perspective for the student. The subject will be given as a series of seminars by eminent outside speakers, supplemented by the regular faculty, who will supervise the students in project studies. This subject will complement the freshman elective, Aerospace Engineering, 16.82, which presents to the student the scope of disciplines encompassed by the field of aerospace technology and their application in developing the total system.

The undergraduate curriculum is thus in a continued state of change and growth, as the Department attempts to respond to the needs of society as these may best be served by the aerospace engineer. The experiments in undergraduate instruction at freshman and sophomore level, the Creative Engineering Symposium, our project-type systems and laboratory subjects, and the new subject in professional engineering, are examples of the way this Department is attempting to meet this challenge.

Winners of the undergraduate awards were: the James Means Memorial Prizes to Willard J. Basner Jr. '69, James P. Kornberg '69, and Gordon K. Mandell '69; the Henry Webb Salisbury award for outstanding academic performance to Alan S. Willsky '69; the Luis de Florez awards for "ingenuity and original thinking" to Isaiah M. Blankson '69, Alan H. Epstein '70, Robert A. Fleming '71, Bruce I. Nappi '69, Thomas B. Smith III '69, Lawrence A. Stelmack '69, Alan S. Willsky '69, and Earl Withycombe II '70.



## THE GRADUATE SCHOOL

A slight decline was evident in graduate enrollment for the year. This continues a trend begun in 1965-66, during which period the all-time peak enrollment was 180. A comparison of this year's figures with the previous year is as follows for the two terms:

	<u>Fall 1967</u>	<u>Fall 1968</u>	<u>Spring 1967</u>	<u>Spring 1968</u>
Regular	169	157	150	150
Special	83	68	56	46

The 7 per cent drop in fall enrollment virtually coincides with the 6 per cent fewer degrees awarded for the year. Most marked is the smaller number of doctoral degrees:

	<u>S.M.</u>	<u>E.A.A.</u>	<u>Ph.D. Sc.D.</u>	<u>Total</u>
1967-68	54	6	23	83
1968-69	61	4	13	78

Despite these decreases, the applications and acceptances for next year show no evidence of any long-range implications at this time. We continue to face competition among several leading graduate schools. This, in combination with simultaneous financial support constraints, uncertainties associated with the draft, and overall trends for engineering interest relative to other professions, leaves little chance for a valid conclusion about any single dominant influence on recent fluctuations.

Slightly more than half of the student group is involved in doctoral study, 4 per cent are seeking the Engineer degree, and the remainder consider the Master's degree their immediate goal.

Since only 22 fellowship awards are currently under the control of the Department (down from 27 last year), the support burden must be borne by either a sustained laboratory program or a larger number of self-generated sources on the part of the students.

Foreign students now comprise one-third of the graduate students and 37 per cent of the applications for 1969-70. Such levels are to be compared with about 22 per cent foreign for the Institute's Graduate School overall. Approximately one-half of our foreign applications continue to be from India and Taiwan, and require financial aid in nearly every case. Unfortunately, the foreign interest is substantial for fluid mechanics, an area which cannot at present furnish assistantships for all those requesting them.

One year ago there was a general opinion nation-wide that the draft would curtail graduate education seriously. Some portion of the 7 per cent decrease experienced this year is undoubtedly related to this, but

neither the Institute nor this Department has experienced large effects.

The dominant subject considered this year by the Institute Committee for Graduate School Policy has been the classified thesis. Such theses have required special review and authorization from this Committee for some time, and these pressures have led to a situation in which none are in progress in this Department and only a few in all of M.I.T. The Department has continued to emphasize both the need for individual academic freedom and discretion and the tremendous educational benefits of work in many areas requiring classification.

The Department Graduate Committee has operated this year under the leadership of Professor Judson R. Baron. The Doctoral Committee has operated under the chairmanship of Professor James E. McCune and has continued to deal effectively with the problems associated with the Department's large doctoral program. In particular, the fall 1969 qualifying examination has been moved up to October in an attempt to eliminate interference with regular subject study and assistantship duties.

Following the development this year of a written guide to the requirements of the Engineer degree, Professor H. Philip Whitaker accepted chairmanship of a five-man group (representing the Department's interest areas) which will oversee the Engineer degree candidates' programs. His group will insure a consistent breadth of study for the E.A.A. and, most important, a uniform level of acceptable Engineer theses.

The Graduate Committee this year initiated an early admission procedure for our own undergraduates. Fifteen seniors took advantage of this in the fall of 1968, and several juniors are now indicating an interest prior to their senior year. A minimum requirement of 4.1 for seniors and 4.3 for juniors is necessary in order for early consideration to be given. A similar process may well be advantageous for external applications, although the criteria for granting early admission necessarily will differ. It is clear that many schools, including other M.I.T. departments, have made admission known to superior applicants long before the customary April 1 date for financial aid announcements. For our undergraduates, such early consideration does seem attractive, since it involves no real obligation on their part while offering a considerable reduction in fourth-year pressures.

The Interdepartmental Doctoral Program in Instrumentation, under Professor Walter Wrigley's chairmanship, is continuing at a healthy level, with approximately 30 students in various phases of their work. Twenty faculty members participated in thesis and examination work. Close association of thesis research with the departmental laboratories and a fine esprit de corps continue to mark the program. A major change in the program is the adoption of a qualifying examination. This was necessitated by

the increasing fraction of students not known well by the faculty at the time of admission, as well as by the larger number of professional areas selected by the students. Inclusion in this examination of a required oral part with some material from the student's previous work, such as an S.M. thesis, was well received by both faculty and students, and allowed continuation of the closer understanding between student and faculty that has always distinguished this program. The committee decided to retain a language requirement: one relevant language at the two-term intensive level.

#### **THE GRADUATE SCHOOL AND THE INSTRUMENTATION LABORATORY**

For many years the Department has enjoyed a close and mutually beneficial association with the Instrumentation Laboratory. This grew naturally out of the professional interests of our teaching group in guidance and control, and the fact that for many years Professor C. Stark Draper served jointly as Director of the Laboratory and Head of the Department. To enhance this relationship further and to stimulate similar cooperation with Lincoln Laboratory, the Inter-Laboratory Research Council was formed in the fall of 1968. Chaired by Professor Wallace E. Vander Velde, the Council took as its objective the encouragement of cooperation between the Department and the Special Laboratories, this activity being initiated well in advance of the appointment of the Review Panel on the Special Laboratories. This cooperation was recognized as taking many forms:

Laboratory projects stimulate and sponsor student thesis research.

Laboratory staff constitute a reservoir of expert talent for consultation, lectures, and project assistance.

The faculty provides expert consultation to and active participation in laboratory projects.

Student participation brings latest methods and fresh ideas to laboratory projects.

Student participation in laboratory projects often leads to better employment opportunities after graduation.

It is the objective of the Council to stimulate all of these and other possible forms of interaction.

As a first step, the Council chose to encourage the stimulation and sponsorship of thesis research by laboratory projects. It is believed that progress toward this objective will also enhance the other forms of cooperation. To this end, teams of two (one laboratory staff member and one faculty member) were organized and assigned responsibility to inquire into the activities of the laboratory group represented by the laboratory staff member of the team and to identify areas of possible thesis research. These research areas have been given a brief description on a

form prepared for this purpose, and the persons to be contacted by interested students are noted. About 70 such research areas have now been identified in the two laboratories, and the descriptions have been filed in an indexed notebook. Copies of the notebook are maintained in the Department Graduate Office and Library.

This first step was completed late this spring, so there is as yet no experience with student response. It is expected that our students will appreciate this opportunity to scan the areas of laboratory activity next year, when they begin to consider subjects for their thesis research. In the meantime, the Council is considering what steps might follow, especially in the light of the recommendations of the Review Panel on the Special Laboratories.

The contact with real engineering problems, which this Laboratory provides for our students, is considered to be of inestimable value in accomplishing the aims of this Department of assuring that the graduates of any degree level will be motivated towards application of their skills for the fulfillment of the needs of society, the true function of the engineer. Without the Laboratory, it is considered unlikely that the Department would be able to undertake the types of systems analyses and integration which form the backbone of modern aerospace engineering.

#### THE FACULTY

Promotions of Department faculty members included Joseph Bicknell, Harold Y. Wachman, and Emmett A. Witmer to Professor, and Norman D. Ham, Walter M. Hollister, and Albert Solbes to Associate Professor. Amos Levin was appointed Assistant Professor in February.

Dr. Robert C. Seamans Jr. served this year as the Jerome Clarke Hunsaker Professor of Aeronautics and Astronautics, but was called to Washington to serve as Secretary of the Air Force prior to completion of the year.

The Department was fortunate in having as Visiting Professor, Dr. Ernst A. Steinhoff, Chief Scientist of Holloman Air Force Base, whose untiring efforts and contributions to the Department were deeply appreciated. In addition to contributing to the undergraduate space systems subject in the fall, he undertook full responsibility for the advanced systems subject in the spring term, and found time to establish the Soaring Association, of which he served as the first president.

Professor Robert L. Halfman returned from India, where he served as Director of the Kanpur Indo-American Program, and assumed his duties as Deputy Head of the Department while also serving as M.I.T. representative on the Consortium Steering Committee of the Kanpur program. Professor Yao T. Li, nominally on sabbatical, continued to contribute to

the activities of the Department through the organization of the Symposium on Creative Engineering. Professor Christoph Haberland of the Technical University of Berlin spent the year as Visiting Professor of Aeronautics and Astronautics, and contributed appreciably to the teaching activities of the Department through seminars and participation in subject work. Professor Heinrich Hertel, also of the Technical University of Berlin, spent a month as Visiting Professor. Michael Judd of the University of Southampton was Visiting Associate Professor and helped greatly with the activities of the Aerophysics Laboratory. The Department is looking forward to welcoming Jean F. Louis as Associate Professor, and James D. Callen and Renwick E. Curry Jr. as Assistant Professors for the coming year.

Professor Louis L. Bucciarelli Jr. received the Baker Award for excellence in undergraduate teaching.

Professor Secor D. Browne left in February to assume the duties of Assistant Secretary of Research and Technology at the Department of Transportation.

Finally, it was with regret that the Department took leave of its head, Raymond L. Bisplinghoff, and welcomed him with pleasure as the new Dean of Engineering.

#### SPECIAL LECTURES AND SEMINARS

The 11th Minta Martin Lecture was presented on March 11 by Professor Seamans and was entitled "Action and Reaction." This thoughtful lecture was an outstanding contribution to an understanding of the problems of complex systems development and was well received by a large audience in the Compton Lecture Hall. The lecture was repeated at the University of Maryland and at the NASA Lewis Research Center.

Professor Otto C. Koppen presented the 10th Lester D. Gardner Lecture on May 23, discussing the history of short takeoff and landing in a lecture entitled "The Historical Development of the STOL Aircraft." New light was thrown on many of the problems of achieving safe, short takeoff characteristics of STOL aircraft, and the lecture was greatly enjoyed by the large audience.

Under the continuing leadership of Professor James W. Mar, the Department sponsored a full schedule of 29 lectures by leaders of the various fields of aeronautics and astronautics in the Department seminar series. These were as follows:

PROFESSOR A. K. RAO, Indian Institute of Science

"Aerostructures Research at the Indian Institute of Science, Bangalore"

PROFESSOR OLGIERD C. ZIENKIEWICZ, University of Wales, School of Engineering, University College of Swansea

“New Paths in Finite Element Analysis — Isoparametric Formulations”  
(Joint seminar with Civil Engineering)

PROFESSOR OLEG BELOTSEKOVSKII, Physical-Technical Institute of  
Moscow

“The Impact of Space Exploration on the Development of General and  
Specialized Education”

EDWARD J. SCHWARZ, Vought Aeronautics Division, LTV Aerospace  
Corporation

“A Universal Hypersonic Test Vehicle”

JAMES FULLER, Unit Chief of Structures Research for the Commercial  
Airplane Division, The Boeing Company

“Gust Criteria and Analytical Techniques Used in the Boeing 747”

WALTER DOLL, Chief Engineer, Pratt and Whitney Aircraft Division

“Trends in Aircraft Engine Development”

HERBERT G. WEISS, Division Head, Lincoln Laboratory

“A Concept in Air Traffic Control”

COMMANDER THOMAS M. KASTNER, Naval Air Test Center

“Problems in Flight Testing”

DR. JOHN J. MC CARTHY, Vice President of Research and Engineering,  
North American Rockwell Corporation

“Systems Engineering Management”

PROFESSOR WILLIAM M. WILLMARTH, University of Michigan

“The Structure Turbulence in the Boundary Layer. A Review and Re-  
cent Results”

DR. BERNIE PIAEWONSKY, Institute for Defense Analyses

“Aircraft Performance Revisited”

DR. A. JAMES LINCOLN, Sperry Rand Research Center

“Direction Cosine Computation for Strapped-Down Inertial Guidance”

HAROLD L. EHLERS, Autonetics, Flight Controls Project Office

“Gust Alleviation Control Systems”

PROFESSOR HOLT ASHLEY, Stanford University

“Aeroelastic Optimization”

PROFESSOR PETER B. S. LISSAMAN, California Institute of Technology

“The Jet Flap”

PROFESSOR RENWICK E. CURRY JR., Cornell University

“Estimation and Control with Quantized Measurements”

DR. JEN-SHIH LEE, University of California

“Slow Viscous Flow in a Lung Alveoli Model”

PHILIP DONELY, NASA Langley Research Center

“Operating Practices and Experience as Related to Aircraft Airwor-  
thiness”

PROFESSOR ERNEST E. SECHLER, California Institute of Technology  
"Review of Status of Cylindrical Shell Buckling Problems"

WILLIAM C. BRODING, AVCO Missiles Systems Division  
"Current Problems in Re-Entry Vehicles' Structural Design"

1. Design, E. J. Smith, Structures Project Engineer
2. Test, Frances A. Ottati, Chief of Structures Laboratory
3. Analysis, Robert Roth, Leader of Staff Research Group

PROFESSOR MICHAEL JUDD, Massachusetts Institute of Technology  
"Some Theoretical Aspects of Wind Tunnel Dynamic Testing"

PROFESSOR HEINRICH HERTEL, Massachusetts Institute of Technology  
"Bio-Engineering"

PROFESSOR CHRISTOPHER HABERLAND, Massachusetts Institute of Technology

"Similarity Methods for Investigation of Thermal Behavior of Rocket Propellant Tanks"

PROFESSOR ERNST A. STEINHOFF, Massachusetts Institute of Technology  
"Reusable Boosters"

DR. C. STARK DRAPER, Massachusetts Institute of Technology, Instrumentation Laboratory

"Guidance in Space — An Example of Pioneering Technology"

PROFESSOR FRED E. C. CULICK, California Institute of Technology

"Some Results for Unsteady Combustion in Solid Propellant Rockets"

PROFESSOR HENRY VELKOFF, Ohio State University

"Boundary Layer Discontinuities on Helicopter Rotor Blades"

PROFESSOR JACQUES VIDAL, University of California

"Identification Problem in Biological Sensory Receptors"

DR. ALBERT L. HOPKINS JR., Massachusetts Institute of Technology, Instrumentation Laboratory

"Unified Aerospace Information Processing"

Of special note was the symposium by Philip Donely, Chief of the Flight Mechanics and Technology Division at Langley Research Center. After the seminar students and faculty had dinner with Mr. Donely in the Student Center. The Department provided a subsidy so that the cost of the meal was nominal. It was a highly successful venture in that it combined student-faculty interchange and dialogue outside the classroom with student-faculty-speaker discussions on a topic that was understandable to all. In addition, the easy sociability of the sherry hour and the dinner provided the proper backdrop.

A determined effort will be made to schedule about two of this kind of affair for each term.

A series of seminars dealing with flight transportation was organized by Professor Browne with the following speakers:

SCHOOL OF ENGINEERING

JOHN G. BORGER, Pan American World Airways  
"Airline Aircraft Requirements"

MELVIN A. BRENNER, American Airlines, Inc.  
"Airline Scheduling"

ROBERT E. GRIFFIN, Northeast Airlines, Inc.  
"Airline Forecasting"

KEARNEY G. ROBINSON, Boeing Company  
"Air Commerce Systems Constraints"

STUART G. TIPTON, Air Transport Association of America  
"Airline Financial Requirements"

JOHN R. WILEY, Port of New York Authority  
"Airports and Air Terminals"

HONORABLE JOHN CROOKER, Civil Aeronautics Board  
"Air Transportation as a Regulated Public Utility"

A series of seminars in measurement and control was organized by Professor Shaoul Ezekiel to encourage more experimental activities. The speakers were:

ROBERT VAR, NASA Electronics Research Center  
"The Laser Gyro"

GEORGE REYNOLDS, Technical Operations, Inc.  
"Holography and Its Application in Aerospace Research"

PROFESSOR ROBERT C. SEAMANS, Massachusetts Institute of Technology  
"Returns from Space Research"

ALFRED C. CONROD, M.I.T. Experimental Astronomy Laboratory  
"Measurements for Surveys of Earth Resources"

JAMES N. HALLOCK, NASA Electronics Research Center  
"Star Pattern Recognition Using Holography"

PROFESSOR RAINER WEISS, Massachusetts Institute of Technology, Department of Physics  
"Some Experiments in Gravitation"

PROFESSOR LAURENCE R. YOUNG, Massachusetts Institute of Technology  
"Man's Internal Inertial Guidance System"

PROFESSOR ERNST A. STEINHOFF, Massachusetts Institute of Technology  
"Exploitation of Extra-Terrestrial Resources"

**THE DIVISIONS OF INSTRUCTION**

The Department continued to operate through the five divisions of instruction, and their activities are briefly summarized in the material which follows:

**AERONAUTICAL AND ASTRONAUTICAL SYSTEMS**

The Aeronautical and Astronautical Systems Division, under Professor Rene H. Miller, included the following faculty members: Professors



Frank K. Bentley, Joseph Bicknell, Secor D. Browne, Norman D. Ham, Jack L. Kerrebrock, Otto C. Koppen, E. Eugene Larrabee (absent), Yao T. Li (absent), Paul E. Sandorff (absent), Robert C. Seamans Jr., Robert W. Simpson, Ernst A. Steinhoff, and H. Philip Whitaker.

Under the direction of Professor Steinhoff, the graduate elective subject, Advanced Space Systems Engineering, 16.74, this year treated the problem of establishing a lunar industrial laboratory. This subject is an exercise in professional engineering application. The students are organized in several groups, each taking a portion of the total system and coordinating their activities in meetings with the group leaders. Eight faculty members participated in the subject, presenting seminars and acting as group advisers. In addition, a series of outstanding guest speakers contributed to the program and included:

PROFESSOR WILLARD F. LIBBY, University of California  
"Space Chemistry"

PROFESSOR WILLIAM R. MICHELSON, Colorado State University  
"Electrical Propulsion System, Status and Future"

PROFESSOR JOHN J. GILVARRY, Stanislaus State College and The Rand Corporation  
"Selenological History of the Moon"

FRANK WILLIAMS, NASA Future Project Office  
"Spacecraft Design, Status and Future"

PAUL R. MILLER, NASA Office of Advanced Research and Technology  
"Nuclear-Electric Power Plants, Status and Future"

JOSEPH PECORARO, NASA Office of Advanced Research and Development  
"Status and Future of Life-Support Systems"

As usual, the high point of the program was the visit to Cape Kennedy on May 16, which coincided with the APOLLO X launch. The transportation for this trip was provided by courtesy of the U.S. Air Force.

Interest in flight transportation continued to run high, with increasing emphasis on operations analysis and optimization techniques applied specifically to problems in this area. With the addition of Professor Amos Levin, a new subject expanding the treatment of these topics will be added to the three now given in this area. As the reputation of this Department is becoming more widely known through research in routing, scheduling, and airline management decision systems, as well as through studies of short-haul air transportation systems and vehicles optimized for such systems, an increasing number of students are being attracted to these activities, including many students from abroad.

#### STRUCTURES, MATERIALS, AND AEROELASTICITY

The Division of Structures, Materials, and Aeroelasticity, headed by Pro-

fessor James W. Mar, included the following faculty members: Professors Raymond L. Bisplinghoff, Louis L. Bucciarelli Jr., John Dugundji, Norman D. Ham, Theodore H.-H. Pian, Paul E. Sandorff (absent), Pin Tong, Sheila E. Widnall and Emmett A. Witmer.

During the spring term, a special subject was given on the theory and application of the so-called advanced composites. Nine speakers from industry gave two-hour lectures to the class. The cooperation and willingness of the companies to send their key personnel to the lectures were extremely gratifying. The lists of both the material covered in class and associated industry speakers follows:

ROBERT NEFF AND LIEUTENANT MELVIN WEST, Air Force Materials Laboratory

History, costs, problems, and future prospects of filament and tape production.

DR. EDWARD M. LENOE, AVCO Space Systems Division

Single ply and laminate properties. Correlation of theoretical results with experiments. Test specimens. Three-dimensional composites.

DR. MAURICE A. STEINBERG, Lockheed Aircraft Corporation

Potential of composites for aircraft. Lockheed design experiences. Composites as viewed by a metallurgist. Rolls Royce applications to airbus engine.

DR. REID R. JUNE, The Boeing Company

Application to commercial aircraft. Joints. Reinforcement of metal. Cost per pound saved. Manufacturing technology.

ARTHUR AUGUST AND RICHARD HADCOCK, Grumman Aircraft Engineering Corporation

Design analysis, tradeoffs, manufacturing and quality control. Costs. Test specimens. Biaxial properties. F14-A wing.

MAX WADDOUPS, General Dynamics Company

Characterization and design allowables. Synthesis of an isotropic plate and wing box structures. Minimum weight design. Fatigue.

CHARLES SPAETH, Pratt and Whitney

Metal matrix composites. Applications to air-breathing engines. Dynamic constraints. Joints and attachments.

WARREN STRATTON, Boeing Vertol Company

Application to helicopter rotor blades and v/STOL (Vertical Short Take-off and Landing) propellers. Fatigue-critical structures. Performance gains. Micromechanics.

GEORGE PETERSON, Air Force Materials Laboratory

Overview of exploitation programs. Present status. Future prospects. First, second, and third general applications.

The two-subject sequence on finite element methods was continued

under the supervision of Professor Pian, and major revisions of the content were made so that all the major problems of the finite element methods in structural mechanics were covered. The basic tools were given in the first term so that during the second term each student could work on an individual term project on a certain development of the finite element method.

#### MECHANICS AND PHYSICS OF FLUIDS

Professor Leon Trilling was in charge of the Mechanics and Physics of Fluids Division, which includes the following faculty members: Professors Judson R. Baron, Joseph Bicknell, Eugene E. Covert, Morton Finston, Michael Judd, Marten T. Landahl (absent), W. Stephen Lewellen, James E. McCune, James P. Moran, Christopher K. W. Tam, Edward S. Taylor, Harold Y. Wachman, and Sheila E. Widnall.

Since flight vehicles operate much of the time in a fluid environment, and since energy exchange in a fluid medium plays a key role in providing them with thrust, subjects in the mechanics and physics of fluids constitute an important part of the undergraduate instruction offered to students.

They include a one-term subject, Aerodynamics, 16.02, designed by Professor Covert and built on a firm foundation of thermodynamics and mechanics. This subject, taken by many of the undergraduates, discusses the many ways in which the fluid medium interacts with the flight vehicle, inducing forces, moments, and heat exchange with it. Those students especially interested in fluid mechanics may take an alternative, Gas Dynamics, 16.03, which treats gas dynamics in greater depth.

Two undergraduate electives are available to students interested in continuing work in the field. Topics in Fluid Mechanics, 16.031, provides them an opportunity to apply their knowledge to an analytic understanding of boundary layers, lifting surfaces, and other specific problems of aeronautical interest. Aerodynamics of Flight Vehicles, 16.11, discusses, in a practical way, the drag of laminar and turbulent boundary layers, aerodynamic forces on various configurations, and elements of stability and control.

At the graduate level, the Department offers a series of full-year subjects in compressible, viscous, and rarefied gas dynamics, in the aerodynamics of wings and bodies, and in applied aerodynamics. The division is now designing a single full-year subject to serve as the core of graduate instruction in fluid mechanics. All graduate students interested in the field will take it and it will allow treatment of advanced topics in a more flexible and effective way.

## INSTRUMENTATION, CONTROL, AND GUIDANCE

With Professor Yao T. Li absent on sabbatical leave, the Instrumentation, Control and Guidance Division was led by Professor H. Philip Whitaker and included the following faculty members: Professors Milton U. Clauser, John J. Deyst, C. Stark Draper, Shaoul Ezekiel, Robert L. Halfman, John V. Harrington, Walter M. Hollister, E. Eugene Larrabee, Winston R. Markey, Walter McKay, Jacob L. Meiry, Robert K. Mueller, James E. Potter, Wallace E. Vander Velde, Walter Wrigley, and Laurence R. Young, with Dr. Ramon L. Alonso, Dr. Richard H. Battin, Dr. Elmer J. Frey, Dr. John Hovorka, Dr. A. James Lincoln, and Dr. Robert G. Stern.

The activities of the Instrumentation Laboratory continue to be a source of strength to the educational program of this division. Ways of making effective use of the digital computer as a teaching aid are being pursued in the basic undergraduate automatic control subject, which serves as a prerequisite to most of the division's graduate subjects. Time-sharing programs have been written and are being revised and modified. Similarly, the use of the computer as a design synthesis tool is being brought into the graduate subject in automatic control of flight vehicles. Professors McKay, Deyst, and Whitaker have been associated with these efforts.

Professor Ezekiel has expanded the laboratory experience available to the students both in a regular subject offering and for special laboratory projects. In the spring term, he introduced a new subject, entitled Applied Modern Optics, which covered topics such as properties of light, manipulation of light, and lasers, and applications such as holography, laser gyro, and precision interferometric measurements.

The pressure to add more current material to the crowded schedule of Statistical Problems in Automatic Control, 16.37, Professor Vander Velde's subject, has been relieved by the offering of a follow-on subject, Estimation and Control of Stochastic Processes, 16.371, by Professor Deyst. This two-term sequence is one of the strongest offerings in stochastic estimation and control available at M.I.T., and indeed at most other universities as well. Applied Optimal Control, 16.39, taught by Professor Vander Velde, continues to draw students from the Departments of Electrical Engineering and Mechanical Engineering, as well as from this Department, since it is the only M.I.T. subject which centers attention on computational techniques for finding the solutions of optimal control problems too complex to admit analytic solution.

The thesis supervision work of this division continues to be too heavy. This is indicative of the popularity of modern guidance, estimation, and

control theory among the Department's students, and of the fact that faculty strength in this area is numerically not equal to the demand.

Professor Meiry had a highly successful Industrial Liaison Symposium on deep submergence systems during January.

Life Support and Human Performance in Manned Systems, 16.43J, taught by Professor Young and Professor Thomas B. Sheridan of the Department of Mechanical Engineering, was greeted enthusiastically by the students, who came from four departments. The subject still seems somewhat fragmented, partly because of its reliance on guest speakers and partly because of the volume of new material exposed. Plans for next year call for improving the continuity and scope by giving introductory lectures preceding each of the half-dozen segments of the subject. The required individual projects in the life support area show the wide range of interest and at times extraordinary imagination of the students. In view of the broad coverage of life support given in the lectures and reading, the project offers an opportunity for each student to delve deeply into one area of particular interest to him and, although time-consuming for both faculty and students, it is considered quite worthwhile.

Professor Young is in charge of a Special Summer Program on Aerospace and Undersea Medicine to be given with Dr. Sherman Vinograd of NASA and guest lecturers in August, 1969.

#### PROPULSION AND POWER

The Propulsion and Power Division of Instruction is under the leadership of Professor Jack L. Kerrebrock and includes the following faculty members: W. Stephen Lewellen, James E. McCune, David A. Oliver, Albert Solbes, David B. Stickler, Christopher K. W. Tam, and Edward S. Taylor.

The subject offerings in propulsion and power were distributed among the staff as follows:

##### Fall Term

- 16.54 Aircraft Engines — Kerrebrock
- 16.55 Ionized Gases — Solbes
- 16.561 Nuclear Rockets — Lewellen

##### Spring Term

- 16.53 Rocket Propulsion — Stickler
- 16.531 Mechanics of Two-Phase Flows — Tam
- 16.562 Space Power — Oliver
- 16.60 Vortex Flows — Lewellen

In addition, the members of the division taught several subjects which relate closely to propulsion and power. Thus, in the fall, Professor Tam

taught Gas Dynamics, 16.03, and Professor Stickler participated in Experimental Projects, 16.62, while in the spring Professor Solbes taught Thermodynamics and Statistical Mechanics, 16.001, Professor Kerrebrock participated in Aerospace Engineering, 16.82, and Professor Lewellen participated in Advanced Space Systems Engineering, 16.74. This breadth of participation, in both the undergraduate and graduate teaching, has been useful in stimulating a somewhat closer coupling of the propulsion subjects to others in the Department.

Twenty graduate research programs, 13 doctoral and seven Master's, were supervised by members of the division, who also participated in several doctoral programs in other divisions and in the Department of Mechanical Engineering. This portion of the teaching activity is increasing in proportion to the formal subject load.

A new graduate subject, Introduction to Plasma Kinetic Theory, 16.59, was introduced by Professor McCune last fall. The subject was well attended and attracted students from the Departments of Physics, Nuclear Engineering, Electrical Engineering, and Mathematics.

#### **THE RESEARCH LABORATORIES**

The Department continues to rely heavily on its research laboratories to provide meaningful activities for support of graduate theses and to provide the faculty with an opportunity to conduct the advanced research essential for insuring a high quality of teaching and professional contribution. The Department is organized for research into two divisions, the aerospace division and the instrumentation division. The aerospace research division includes several laboratories organized around the interests of specific faculty members and directly under their control. These include the Fluid Dynamics Research Laboratory, the Aerophysics Research Laboratory, the Aeroelastic and Structures Research Laboratory, the Wright Brothers Wind Tunnel Facility, the Space Propulsion Laboratory, the Measurement Systems Laboratory, the Man-Vehicle Control Laboratory, the Gas Turbine Laboratory, the Flight Transportation Laboratory, the Plasma Physics and Space Sciences Laboratory, and various facilities used for individual research by faculty members. The instrumentation division or Instrumentation Laboratory includes the guidance systems section, the guidance component section, and the guidance test facilities sections.

The aerospace division has equipment for research applicable to all regions of flight, from hovering to interplanetary. The instrumentation division pioneers in the development of control and guidance equipment

## DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

for aircraft, missiles, and space vehicles. Inertial guidance receives special attention, and the Instrumentation Laboratory is equipped with advanced facilities for research on all phases of control and guidance.

### FLUID DYNAMICS RESEARCH LABORATORY

The Fluid Dynamics Research Laboratory is a grouping of four faculty members, Professors Trilling, Moran, Wachman, and Widnall, and ten graduate students, with one D.S.R. research staff member. Their common thread is an interest in problems in rarefied gas dynamics and in wing theory.

In the summer of 1968, Professors Trilling and Wachman organized the Sixth International Symposium in Rarefied Gas Dynamics, which brought to M.I.T. some four hundred scientists from 16 countries for five days of fruitful discussions and formal sessions. The Proceedings of this Symposium have been published in two volumes by Academic Press (May, 1969).

Research in the interaction of gas molecules with solid surfaces has led to a better understanding of some real gas effects (differences between monatomic and diatomic molecules), of excitation of internal degrees of freedom of the gas, of the mechanism of surface adsorption, and to some new methods of calculating accommodation properties.

Results of detailed measurements of the direction and velocity of argon molecules re-emitted from a platinum surface have been published. Meanwhile, methods for producing higher energy beams were developed and a new larger vacuum facility is being completed.

Meanwhile, studies of the Boltzmann equations by a Fourier transformation method are leading to a class of new exact solutions helpful in computing the expansion of gas jets in vacuum.

Professor Widnall is continuing her studies of lifting surface theory and of the motion of vortices left trailing behind wings of finite span. She has recently begun a new study of the persistence of wakes and their effect on clear air turbulence and is also conducting an analytical and experimental study on the aerodynamics of wings in very close proximity to the ground for application to high-speed ground transportation systems.

### AEROPHYSICS LABORATORY

The Aerophysics Laboratory, under the direction of Professor Finston, and with the participation of Professors Baron, Covert, and Judd, and Dr. Charles W. Haldeman, continued research along the lines indicated with the following list of accomplishments:

1. The new magnetic suspension system is now a fully working six-

degree-of-freedom system, and aerodynamic research is well under way on dynamic stability of various bodies at  $0 < M < .49$ .

2. Using the original suspension system to support a cone in hypersonic flow, oscillations were found to propagate in the near wake and harmonics were also detected.

3. Earlier theoretical studies indicated the possibility of accelerating ionized gases to very high enthalpies and velocities in a traveling wave pump. This year pioneering work on the development of high-power coils and the production of a highly conductive, nonequilibrium plasma was successfully completed along with other areas of development. The Laboratory has just embarked on a crucial experiment to test the predictions and point the way for further work.

4. Successful simulation of blackout of re-entry communication was achieved in the supersonic tunnel, permitting study of this important problem.

There is a continuing effort in the area of high-temperature reacting and radiating flows. New work is concerned with surface chemistry related to ablation problems and involves constructing a molecular beam apparatus with which to examine the surface interactions in some detail.

Facilities development includes the completion of a second-generation magnetic suspension, an associated subsonic ( $M < .49$ ) open-return tunnel and the addition of transonic and  $M \simeq 6.25$  nozzles to the hypersonic facility. A water channel also has been built and is in operation.

The existing supersonic and hypersonic tunnels continue to play a vital role in the research program.

#### AEROELASTIC AND STRUCTURES RESEARCH LABORATORY

A variety of research studies has been carried out in the past year under the leadership of Professor Witmer, with the active participation and supervision of Professors Bucciarelli, Dugundji, Ham, Lewellen, Mar, Miller, Pian, Tong, and Widnall on contracts and grants from the Federal government. The work involved unsteady aerodynamics and vibrations of helicopter rotors, the behavior of some strongly shocked heavy gases, steady airloads on partially erected radomes in gradient flow, and non-linear and parametric vibrations. Static and dynamic elastic and elastic-plastic analyses of simple and complex structures, using both finite-difference and discrete-element methods, and the mechanical behavior of metallic composites were also studied.

A basic study of rotor airloads is continuing with particular attention to noise generation mechanisms and to methods for alleviating the vibration in a helicopter through the use of selective control inputs. Under Professor Widnall research is being conducted with Army Research Office



sponsorship into the aerodynamics of blade-vortex interaction and radiated noise. She is participating with Professors Ham and Lewellen in a parallel program sponsored by NASA on the dynamic load resulting from blade-vortex interaction. Her future plans include development of an anechoic chamber for the low-speed tunnel in the Aeroelastic Laboratory in order to derive information on the nature of rotor-generated noise on VTOL aircraft. This research, performed with Professor Simpson of the Flight Transportation Laboratory, will be used in a systems study on the important problem of noise generation and means of reducing the noise signature of VTOL aircraft operating in urban centers.

Under Professor Ham, the effects of rotor torsional flexibility on the airloads on rotors operating at high advance ratios are being studied experimentally. Also, various means for making a rotor blade airfoil less prone to experiencing stall flutter are being explored.

In support of studies by the Northeast Radio Observatory Corporation (NEROC) of the design feasibility of a large radome-protected radio telescope, the Laboratory has been conducting wind tunnel studies first to produce various types of gradient (thick boundary layer) flows and then to measure the airloads on partially erected radome models in these gradient flows.

Professor Dugundji and his students have been investigating the parametric and nonlinear large-amplitude vibrations of a pendulum as background for dynamic instability studies of structures. Both theoretically and experimentally, transient and steady-state responses have been studied, and good theoretical-experimental agreement has been found. The presence of various steady-state limit cycles, including some little-known subharmonic resonances at one-third, one-fourth, and one-fifth of the forcing frequency have been observed. It has been found that if the damping is small enough, many subharmonic and superharmonic limit cycles are possible.

Under the supervision of Professors Pian and Witmer, discrete-element variational techniques are being developed to analyze anisotropic shells with cutouts and stiffeners, subjected to thermal and mechanical static loads; Washizu's general variational principle has been applied to the discrete-element method (also known as the finite-element method), and many alternate variational discrete-element models, each with particular advantages, have been identified and discussed. Two of these models have been developed in detail for a doubly curved quadrilateral element of a shell of revolution. Earlier shell-of-revolution discrete-element formulations have been applied to analyze a variety of structures to explore structural modeling problems; these methods have also been extended to predict the dynamic response of shells to transient loads. In addition,

discrete-element formulations have been developed and evaluated for single-layer cylindrical shells and for sandwich beams, flat plates, and cylinders, including transverse shear deformation effects.

Professors Pian and Tong have been studying a sequence of finite-element variational models and the criteria for the convergence of the finite-element method for structural analysis purposes. The finite-element method has also been applied to analyze liquid sloshing and liquid-structure motion interactions. Convergence of this procedure to the exact solution as the finite-element sizes decrease has been demonstrated. The application of this method to analyzing blood flow through passages with flexible walls is also being explored.

The contribution of this Office of Scientific Research-sponsored program to the basic problems in finite-element methods in continuum mechanics has been well recognized in this country and abroad. During the summer of 1969, a U.S.-Japan symposium on Matrix Methods in Structural Analysis and Design will be held in Tokyo. Professor Pian has been designated as one of the ten official delegates by the National Science Foundation and has been invited to present the opening lecture, "Basic Theory of Finite-Element Method." Professor Tong has also been invited to participate in the symposium by presenting a paper, "Application of Finite-Element Method to Fluid Mechanics Problems."

An investigation of various concepts for the containment and/or control of fragments from burst rotors of aircraft engines as well as of finite-difference and discrete-element methods for predicting the dynamic structural behavior of such containment devices is being conducted by Dr. John W. Leech, R. Bruce McCallum, and Professor Witmer for NASA.

The large-deflection elastic-plastic dynamic response analysis of thin arbitrarily shaped Kirchhoff shells which are subjected to impulsive or transient loading has been formulated in tensor and finite-difference form. This powerful and general formulation has been embodied in a computer program, PETROS 2, which has been applied to predict the transient deflection and strain responses of an impulsively loaded metal cylindrical panel for which reliable experimental results exist. Excellent theoretical-experimental agreement has been found. The accommodation of additional structural complexities, such as variable thickness and multilayers, by this finite-difference method is currently under investigation by Dr. Luigi Morino, Dr. Leech, and Professor Witmer.

Professors Mar and Bucciarelli and student assistants have been investigating some spacecraft structural design problems. One aspect concerns the analysis of the dynamic coupling of small elastic displacements with large rigid-body motions occurring during and after the deployment of extensible or unfolding elements, such as solar panels, from a space-

craft; such coupling can lead to serious stressing and structural failure. Means of treating the highly nonlinear coupled differential equations which characterize this dynamic behavior are being studied. A second problem area involves examining the consequences of employing various simplifying assumptions, such as the Kirchhoff assumptions, to make tractable existing complete but unwieldy formulations for analyzing the static load-deflection behavior of structures wherein arbitrarily large deformations occur. These studies are also expected to be pertinent in the analysis of large nonlinear vibrations for structures of this class.

Under the leadership of Professor Mar, research has been continuing on exploring the mechanical behavior of fibrous metallic composites. The tensile properties of Al-Al<sub>3</sub>Ni eutectic fiber composites with varying fiber spacing have been studied at temperatures ranging from room temperature to 600°C and for various strain rates. Also, the effect of fiber matrix reaction and compound formation on composite strength and fracture has been studied using aluminium-molybdenum fiber composites with different interface compounds; the degree of notch sensitivity of the fibers significantly affects the strength if a 1 per cent compound fraction is used, but a much smaller effect occurs if a 10 per cent or greater fraction of compound is employed. Finally, studies have been carried out to show the strengthening effect of fiber spacings ranging from 0.25 microns to 250 microns using a copper matrix and iron fibers.

#### GAS TURBINE LABORATORY

Since June, 1968, several additional faculty members have become associated with the activities of the Gas Turbine Laboratory, and have initiated new research, mainly focused on the aerodynamics of high Mach number turbomachinery and aircraft engine noises. Additional funding has been sought, the reaction from both industry and government being very favorable.

Personnel who participated in the research of the Laboratory were Professors Kerrebrock, McCune, Oliver, Tam, Taylor, and Stickler, and Professors Richard F. Salant and David G. Wilson of the Department of Mechanical Engineering.

In addition, the Laboratory has had the benefit of extended visits by Professors William R. Hawthorne of Cambridge University, Philip G. Hill of Queens University, and Frank E. Marble of the California Institute of Technology. Professor Yoshio Kataoka of the Akashi Technical Junior College was a Research Associate.

Nine doctoral students conducted research in the Laboratory, four from the Department of Mechanical Engineering and five from this Department. Some six Master's candidates were about equally divided

between the two Departments. Most of these students were supported as Research Assistants, and most were involved in experimental programs.

The main areas of research during the past year were as follows:

**FLOW IN CENTRIFUGAL IMPELLERS** This project, aimed at delineating the flow patterns in centrifugal compressor impellers, has yielded a more detailed understanding of the boundary layer behavior in such rotors, including a technique for estimating separation. It is now completed.

**UNCONVENTIONAL BLADING FOR AXIAL COMPRESSORS** A study of the performance of an axial compressor stage with vortex-generating fillets at the blade extremities, this program has established that compressor performance can be improved by such modifications, particularly at low flow coefficients. This project is completed.

**DROPLET GROWTH IN NOZZLES** This investigation determined, by light-scattering techniques, the droplet sizes attained by condensation of water vapor in air.

**MIXING OF JETS WITH SWIRL** This is an experimental and theoretical program to determine the effect of swirl on the mixing of turbulent jets.

**PERTURBED TURBULENT BOUNDARY LAYER** This experimental program provides measurements of the response of a boundary layer to a two-dimensional step.

**AERODYNAMICS AND NOISE IN TRANSONIC COMPRESSORS** The goal of this project is to determine the mechanisms of noise production in transonic compressors, and their connection to the losses. It was initiated in November, 1968.

**WAKE TRANSPORT IN STATORS** The intent of this program is to clarify understanding of the unsteady flow which results from transport of rotor wakes through stator blades. Flow visualization is being done in water, as well as helium-tracing in a single-stage air compressor.

**UNSTEADY FLOW IN TRANSONIC COMPRESSORS** A blowdown-type, large mass flow freon test facility is being constructed. Its initial application will be a study, by means of optical techniques and time-resolved pressure measurements, of the unsteady flow resulting from blade passing.

**THREE-DIMENSIONAL TRANSONIC FLOW** Techniques are being developed for calculation of the three-dimensional flow in transonic rotors, including shocks, but excluding other viscous phenomena.

**HOLOGRAPHIC FLOW VISUALIZATION** Holographic methods for visualization of sound waves are being developed. Initial applications will be to locate sources of sound in jets and propellers.

The Laboratory has been supported for the last year by the Office of Naval Research, National Science Foundation, General Electric Company, Pratt & Whitney Aircraft, and NASA. Currently, the combined level of funding is approximately \$230,000 per year.

SPACE PROPULSION LABORATORY

In addition to Professor Kerrebrock, who directs the activities of the Space Propulsion Laboratory, faculty members directing research were Professors Lewellen, Oliver, Solbes, and Stickler.

Research activities were centered on the problems of electric power generation and propulsion in space. The Laboratory uses facilities both in Building 31 and the Center for Space Research. Six doctoral and four Master's candidates conducted thesis research, mostly as research assistants.

Research was supported by the Air Force, through the Aero Propulsion Laboratory, the Office of Scientific Research, and the Aerospace Research Laboratory; by NASA; by Lincoln Laboratory; and by United Aircraft Corporation. The level of funding was approximately \$240,000 for the year.

The principal research projects were as follows:

**NONEQUILIBRIUM MHD GENERATOR** The aim of this project is to determine the feasibility of nuclear magnetohydrodynamic power generation. It involves experimental studies of the performance of a large nonequilibrium MHD (magnetohydrodynamic) generator, both with and without diatomic diluents, as well as smaller scale experiments on the bulk behavior of nonequilibrium plasmas.

**GASEOUS NUCLEAR ROCKETS** Studies are under way of the fluid mechanics of vortex containment and of the stability of gases with large radiative heat fluxes.

**ALKALI-COLOID ELECTROGASDYNAMIC GENERATORS** The aim of this project is to study the feasibility of electric power generation in space by means of an electrogasdynamic generator driven by a jet of metal vapor, which, on condensing, produces the required charged colloid.

**PULSED PLASMA THRUSTER** A small pulsed electric thruster, which is in service in a Lincoln Laboratory satellite, is being studied in the vacuum facility of the Laboratory, with the aim of attaining a better understanding of its operation.

**HYBRID ROCKET COMBUSTION** This is an experimental and theoretical study of the mechanisms which limit the regression rate in hybrid rockets and lead to a pressure dependence at high mass fluxes.

LABORATORY FOR PLASMA PHYSICS AND SPACE SCIENCES

The support for this research group has been broadened to include (in addition to continuing funding from the Center for Space Research) funding from the Air Force Office of Scientific Research and the National Science Foundation.

Personnel includes Professor McCune, in charge, and Professor Tam. Dr. James D. Callen will join the group on July 1.

There are currently two doctoral candidates working with the Laboratory. Two, or possibly three, additional students will join the group next year.

Research is focused on the dynamics of plasmas typical of the solar wind, the magnetosphere, and laboratory fusion plasmas. The main thrust of the effort is currently directed toward plasma wave propagation, including instabilities, wave-particle interaction, nonlinear effects, and finite geometry effects.

#### MAN-VEHICLE CONTROL LABORATORY

The Man-Vehicle Control Laboratory, under the direction of Professor Young, includes Professors Li (on leave 1968-69) and Meiry, and Research Associate Anil V. Phatak.

The Laboratory conducts research in a number of areas related to engineering problems of man and his environment, especially his interaction with vehicles. Of major concern has been the investigation of biological control systems, particularly the human sensory subsystems, and the characteristics of manual control. The studies are all conducted on research grants. Operations are in an intimate laboratory milieu in which student research is conducted on projects of interest to faculty and students, and the entire group joins in the evaluation of each experiment. The Laboratory is supported principally by three grants from NASA headquarters. One is in manual control, one in the investigation of the vestibular system and the balance reflex, and one in life-support systems. The National Institutes of Health, through M.I.T.'s basic institutional grant, supports a research associate to work in biomedical applications of this work. Several of the projects have interesting clinical applications which the Laboratory is exploring with colleagues at Harvard Medical School. Work is expected to begin shortly on a fourth NASA grant for study of collision-warning displays for light aircraft.

The Laboratory is sponsoring a Special Summer Program in aerospace and undersea medicine.

Professor Renwick E. Curry, who has worked in system identification, comes to the Laboratory in September from the Cornell faculty and expects to apply his expertise to identification and modeling of biological systems. In addition, Dr. Alfred D. Weiss, a neurologist at the Harvard Medical School, who has worked with the Laboratory as a medical consultant for several years, will move his vestibular and neurological research into the Laboratory and join the staff as a part-time research

associate. His appointment reflects increasing interest in the medical applications of the Laboratory's research. In the life-support area the Laboratory continues to enjoy the assistance of Professor Robert C. Reid of the Department of Chemical Engineering.

Three major research facilities were added during the year.

A general-purpose experimental apparatus for studies of postural control was designed and built. This device permits simulation of any type of active or passive restraint against the feet while measurements of ankle angle, torque, and muscle activity are recorded.

A Link GAT-1 moving base flight simulator was purchased and is being integrated with the hybrid computer to permit three-axis angular motion simulation of any vehicle. It will be used for control and display evaluation, manual control, and vestibular testing, and complements existing simulators.

The Adage AGT-30 computer graphics terminal in the Electronic Systems Laboratory has been used for VTOL display research and it is planned to install a remote console to permit "flying" the displays in the simulators in the Laboratory. The hybrid computer system has been expanded somewhat.

The various research projects carried out during the past year are:

1. Manual control modeling
  - Adaptive characteristics
  - Development of an "aided driven" force control stick
  - Separation of effects of linear and angular motion
  - Multiloop characteristics and instrument scanning rules
  - Aircraft landing and "backside of power curve" approaches
2. Display research
  - Audio localization for collision warning
  - Perspective glide slope display and evaluation
  - VTOL "bottom window" integrated display
  - "Anti-vertigo" display
  - Three-dimensional display
3. Vestibular research
  - Development of model for adaptation
  - Low-frequency otolith stimulation
  - Directional preponderance in semicircular canals
  - Habituation to rotating environment
  - Unified model of vestibular function
4. Eye movements
  - Visual-vestibular interaction
  - Effects of voluntary limb motion (efferent copy) on pursuit movements

- Nonlinear aspects of compensatory eye movements
- Stochastic eye tracking model
- 5. Life support
  - Atmospheres for spacecraft and extravehicular activity
  - Contaminant monitoring
  - Effects of ionization radiation and magnetic fields on the central nervous system
  - Water recovery systems
  - Speech recognition
  - Cardiovascular deconditioning in weightlessness
- 6. Cybernetics
  - Self-reorganizing systems
  - "Learning automata" based on physiological principles
  - On-line system identification
- 7. Postural control
  - Balance reflex experiments
  - Neuromuscular models
  - Extravehicular stabilization from postural signals
- 8. Medical applications
  - Electromyogram processing and display for orthopedic surgeons
  - Postural control diagnostics
  - Eye movement (nystagmus) processing program
  - Intra-ocular pressure measurement
  - Diabetes diagnosis and insulin-glucose modeling

FLIGHT TRANSPORTATION LABORATORY

Professor Simpson assumed direction of this Laboratory when Professor Miller became head of the Department. Professor Levin joined the Laboratory in February. Research activities continued to be concerned with air transportation problems in the Northeast Corridor. Five reports were published dealing with optimal size and frequency of service for v/STOL air systems, fleet routing and scheduling problems for air transportation systems, ground access to major airports, and the effects of vTOL aircraft noise on vertiport locations. Twelve memoranda were written during the year as new internal documents of Laboratory research. Future research will deal with projected air transportation problems in the Northeast Corridor during the 1980's, focusing on the requirements for new airport terminal facilities and a continuing research into optimal scheduling of air transportation systems, the main effort being directed towards the construction of a total Airline Management Decision System (AMDS). Contacts have been established with Northeast Airlines in order to apply



these methods to their fleets when the computerized system is complete. The testing of the methods on real-life transportation systems is important in order to chart the course for future research. Research on airline crew scheduling during the year has attracted the interest of a number of airlines. Some time has been given to investigating the requirements for real-time computer and ticketing systems in future VTOL terminals. This activity will be pursued more intensely during the next academic year.

The Laboratory is seriously restricted in expanding its activities by the lack of suitably qualified professional personnel. There are many research problems and many sources of support for studies in air transportation that presently exist, but the lack of qualified supervisory talent restricts the Laboratory from expanding its activities.

The data file has now reached proportions of 3,000 reports, and work has begun on means of using computer search and access to the file in association with Project TIP (Technical Information Program). This effort should enable the staff of the Laboratory and students in flight transportation to perform research more easily and for the Laboratory to have a current body of research knowledge in the field.

#### WRIGHT BROTHERS WIND TUNNEL

Under the supervision of Professor Bicknell, the Wright Brothers Wind Tunnel and associated building has been upgraded in this past year in a number of important ways. The installation of a new operating console and a major overhaul of the balance components and wiring and of the main motor switchgear has been finished. Painting of the interior of the building has helped produce a favorable working atmosphere. The operation of the tunnel is directed by Frank H. Durgin, recently added to the staff.

The Tunnel has been in productive use for most of the available time in the past year. Graduate students have used it for three theses, running the tests themselves with a minimum of help from the Tunnel personnel. Several small test programs have been run for outside contractors. A major test program was run to evaluate the aerodynamic properties of a four-engine short-haul transport airplane for General Aircraft Corporation. This project has been of great interest to faculty in the applied aerodynamics field, and has sparked classroom discussion and an idea that may improve the wind tunnel testing of such airplane models. Currently, testing of the NEROC antenna radome is being carried out for the Lincoln Laboratory.

Financing of the Tunnel operation and of the test section revision is a major problem. It is planned that more support will be sought to exploit

the excellent technical capability which exists in the aerodynamics of buildings, as well as airplanes.

#### MEASUREMENT SYSTEMS LABORATORY

In January, the Experimental Astronomy Laboratory became the Measurement Systems Laboratory. At the time the Experimental Astronomy Laboratory was founded in 1961, the major activity was the design and construction of telescope stabilization systems for the Smithsonian Astrophysical Observatory. Subsequently, the research interests of the faculty and staff members of the Laboratory have broadened. At the present time the principal effort is in navigation system design. In addition, studies of measurement techniques for those natural phenomena related to navigation, the earth sciences, and gravitational theory are being conducted. The Laboratory's new name is believed to represent its activities more accurately.

The Laboratory is directed by Professor Markey. Participating faculty members are Professors Deyst, Ezekiel, Hollister, and Potter. Professors Whitaker and Wrigley of this Department, Professors Charles C. Counselman and Irwin I. Shapiro of the Department of Earth and Planetary Sciences, Professor Rainer Weiss of the Department of Physics, and Professor Philip Mandel of the Department of Naval Architecture and Marine Engineering provided supervision for many of the research assistants.

Four divisions of research have been established in order to identify the areas of responsibility of those faculty and staff members supervising research assistants and other students. The divisions are (1) aerospace systems, (2) terrestrial measurements, (3) space sciences, and (4) engineering development. Some of the research projects in each of these divisions will be described briefly in what follows:

The activities of the aerospace systems group during the past year fall into five main categories: celestial mechanics, space guidance, control theory, geodetic applications of earth satellites, and terrestrial navigation system design.

A doctoral thesis on the rotation of the planet Mercury was the primary publication in the area of celestial mechanics. Additional work involved the improvement of the Laboratory's trajectory program and an investigation of a possible new method of expressing mathematically the earth's gravitational potential.

A doctoral thesis has been completed in the area of space guidance, the subject being the application of the method of matched asymptotic expansions to the determination of guidance corrections for an interplanetary or a lunar trajectory.

A doctoral thesis in control theory had, as its subject, the optimization of estimates based on quantized measurements. In addition, there is work in progress on applying stochastic control theory to air traffic control.

The work completed in satellite geodesy includes an analysis of radar altimetry measurements made from a satellite and an analytic investigation of methods of incorporating altimetry measurements into the determination of the coefficients of the spherical harmonic expansion for the earth's field. Results of the latter investigation will be contained in a doctoral thesis to be completed this year.

The research on terrestrial navigation system design during the past year has shifted from SST (Supersonic Transport) applications to v/STOL applications. A model for the propagation of errors in a v/STOL prototype navigation system was developed. Flight tests conducted by the NASA Electronics Research Center using a helicopter proved the validity of the model and provided new material for the Department's graduate subject in inertial navigation.

In the division of space sciences, the objective of the research was to determine the feasibility study of certain space experiments concerned with the nature of the gravitational field, as part of a continuing program of investigation of the application of aerospace technology to the measurement of relativistic effects. During the past year research on two experiments started in 1963 has continued.

One experiment being considered is a comparison in earth orbit of the ratio of inert to gravitational mass for different substances, which would allow the accuracy of earth-based Eötvös experiments to be improved by at least four orders of magnitude. This test will be extended to the case in which one of the test masses is a gyroscope of high specific angular momentum. A demonstration of the expected anomalous Eötvös ratio of a spinning body would be of significance to the foundations of general relativity.

Another experiment is the construction of a clock whose period is a function of the gravitational constant. Observation of the period of such a clock in regions of differing gravitational potential could provide a direct and unequivocal test of the validity of the Brans-Dicke gravitational theory. It is expected that a measurement of the magnitude of the gravitational constant (Cavendish experiment) would also result from this investigation.

The two major projects in terrestrial measurements were concerned with airborne gravimetry and barometric altimetry.

A series of flight tests was conducted in an Air Force C-130 aircraft using a gyro-accelerometer as a gravimeter. The necessary accelerometer modifications, the data recording systems, and assembly of a stable plat-

form for the accelerometer were accomplished by laboratory personnel. Gravimeter readings were combined with navigation data recorded by the Air Force Cambridge Research Laboratories to yield reduced gravity observations at flight altitude. These were compared with gravity values extrapolated from ground data; the overall difference for all flight data reduced thus far has a 6 milligal and less than 5 milligal standard deviation for an area 5 degrees on each side. Further data reduction and resolution studies will be accomplished in the next year using newly available altimetry data.

An assessment of the state of the art of barometric altimetry was conducted for NASA Electronics Research Center, primarily from the standpoint of aircraft separation requirements. The result of the study was a recommendation for better calibration, inspection, and maintenance procedures and equipment, especially for general aviation. In addition, work on a feedback type of pressure transducer with a broad measurement appears desirable, particularly for high-altitude aircraft.

Engineering development contained a variety of programs, all of which were related to the design, construction, and test of components and systems for terrestrial navigation. Two programs were an extension of work that has been performed for the Naval Oceanographic Office on Project HYSURCH (Hydrographic Surveying and Charting System).

One of the principal developments on Project HYSURCH was the inverted offshore hyperbolic radio navigation system. The design of the system employs a master station buoy which station-keeps by propulsion, utilizing radio-frequency communication with two anchored slave buoys. During the past year a model of the master station buoy was designed and constructed and the tracking and control system parameters were verified through tests in the M.I.T. swimming pool. Several reports and a documentary film describe this effort. This concept of an unmanned, unmoored, powered, station-keeping buoy utilizing (and participating in) radio navigation transmissions appears to have much utility for other tasks, such as meteorological data platforms, aircraft navigation aids and offshore oil tract location systems.

Another development from Project HYSURCH was the conception of a sonar instrument which would measure water depths explicitly and accurately over a wide area. This instrument has the potential of upgrading bathymetric sensing (for charting purposes) by an order of magnitude. It would provide a depth measurement capability that does not now exist. This device is based on delay-Doppler principles that have been useful in other fields, such as planetary mapping.

The research described above supported 21 research assistants, a visiting engineer from Norway, and four undergraduates. In addition, a

"Summer Institute in Dynamical Astronomy," supported jointly by the National Science Foundation and NASA was held by the Laboratory from June 17 through July 12, 1968. The first two weeks were dedicated to basic concepts and methods of dynamical astronomy, including lectures on celestial mechanics, orbit determination, satellite theory, Hamiltonian mechanics, observational methods, series solutions, and programming. During the third and fourth weeks more advanced subjects such as planetary and lunar theories, the restricted problem of three bodies, spin of planets, applications in the fields of interplanetary and lunar trajectories, guidance and optimization were presented. A total of 120 participants attended the institute.

#### INSTRUMENTATION LABORATORY

Instrumentation Laboratory activities during the year have been extraordinarily successful from the standpoint of technological achievements. The activity was supported by the U.S. Navy, U.S. Air Force, and U.S. Army, as well as NASA and various other civilian agencies. The Laboratory has been subject to strong attacks from some students and several faculty groups, including speeches, handouts, and picketing with threatened occupation of some Laboratory facilities which disrupted normal work during a period of some two months. Through the appointment of the Pounds Panel and the wise consideration of the Panel's recommendations, the situation returned to a reasonable degree of normalcy. Effective research is now continuing.

It is not to be expected that the Instrumentation Laboratory will be free of critical attention from various directions in the future, but it appears that there will be no complete severing of the M.I.T.-Instrumentation Laboratory ties, and that suitable comprehensive tasks of pioneering technology can be accepted in the future without regard to whether or not sponsorship is civilian or military, with or without classification. However, classified projects will be avoided when this is possible and security restrictions will be minimized in all possible ways. It is agreed that when adequate support is available, civilian projects will be given preference to military unless an overriding national emergency exists. With judgment and good will from all of the parties involved, M.I.T. and the Instrumentation Laboratory should be able to continue their past excellent relationship indefinitely.

Guidance and navigation for the APOLLO Command Module and the APOLLO Lunar Excursion Module is a most spectacular success for the Instrumentation Laboratory. Manned trips to the moon with separation and exercise of the Lunar Excursion Module have shown that our efforts are not only theoretically correct but produced designs from which AC

Electronics, Raytheon, Kollsman and other companies have produced systems that have worked in space flight operations without significant flaws. With the approach of APOLLO 11 to carry out the complete moon landing and return mission, all the Instrumentation Laboratory personnel are to be congratulated on an excellent job and with better-than-specification performance delivered on schedule.

POSEIDON guidance systems designed by the Laboratory are now in production. Firing tests with complete missiles have encountered some difficulties, but are now demonstrating excellent performance.

Stabilization and angular control systems for the NASA Orbiting Astronomical Observatory have been designed and built and have passed laboratory performance tests before being installed in vehicles for flight operations.

Deep submergence rescue submarine systems for control, navigation, and guidance have been designed, built as operational equipment, and delivered to Lockheed Aircraft Corporation for sea tests within the next few months. The Laboratory retains a simulator which is being used to train the first crews of hydronauts. Performances of the system as demonstrated by the simulator are excellent and appear to have started a train of thought in the Navy that may revolutionize control arrangements for all submarines and ships.

SEAL, a system based on geometry provided by inertial components, has been built for the Federal Aviation Agency and is now installed in an airplane for shakedown tests. This system is intended to provide geometrical references so accurate that it will be possible to plot radiation field intensities on a map to give consistent locations of radio navigational aids.

Advanced gyro units and specific force integrating sensors have been under engineering study in the Laboratory for two years. The data to be taken under the original arrangement with NASA are now substantially complete. Engineering prototype units are now either under construction or already in test. It appears that the original goal of two orders of magnitude improvement in performance can be achieved. Designs of production prototypes will be started immediately.

SABRE guidance system tests are well along on engineering models. Results are most encouraging. Work is now going forward on new SABRE-type units based on applications of the new inertial sensors. These designs will have improved performance and be smaller in size than the systems now under tests. It is to be expected that ballistic missile effectiveness could be improved greatly by use of these advanced systems.

A most interesting development in the Laboratory has been the VTOL system being carried out for the Army and NASA by Ralph B. Trueblood,

under the supervision of Professors Miller and Whitaker. Recent demonstration tests for Army and NASA personnel with a helicopter have been quite successful. It is hoped that this field of control, navigation, and guidance for VTOL craft, with its far-reaching implications for increased safety in both commercial and military applications, will receive more active attention in the immediate future.

Two years ago, with the establishment of the division of scientific technology, headed by Laboratory staff member Philip N. Bowditch, the Instrumentation Laboratory formally accepted the challenge to emphasize and expand interaction and collaboration with scientific and academic interests both within and outside M.I.T. as a significant part of the Instrumentation Laboratory's efforts.

During the past two years, activities within this division have amply demonstrated the potential and interest both inside the Laboratory and in the academic and scientific communities. Projects initiated and continued in the past year include the following: support to the Woods Hole Oceanographic Institution in the engineering problems associated with their major midwater offshore ocean current program; design, construction and deployment of a major oceanographic instrumentation array off Bermuda in collaboration with the Center for Earth Sciences; the development, construction, and checkout of novel soil mechanics instrumentation in support of the soil mechanics division of the Department of Civil Engineering; design, engineering and construction of a biotelemetric instrumentation system in collaborative support of a project in the Life Sciences Center; a collaborative project with the Department of Metallurgy and Materials Science and the Harvard School of Public Health on computer control of an electron microscope for particulate matter identification and monitoring; the engineering, design, and construction and installation of a Beneoff Tiltmeter instrument at the Agassiz Seismology Station in Harvard, Massachusetts, in support of the Department of Earth and Planetary Physics.

These projects reflect the diverse character of efforts that the Instrumentation Laboratory has participated in during the last year. This listing is not complete, but serves to show the many ways in which a laboratory such as the Instrumentation Laboratory can support and derive benefit from interactions with the scientific and academic community.

One project deserves special mention, as it represents to the Laboratory the desired end objective of continuing collaboration with the M.I.T. campus. This project is called CARS (a demand-responsive public transportation system). The project was conceived and worked on by the students and faculty of several departments under the charter of the Urban Systems Laboratory. During the last year, the Instrumentation

Laboratory was invited to participate with the leaders of the project in the Urban Systems Laboratory as a full collaborator in a major program of implementation of this transportation concept. This project promises to involve a major effort of the Instrumentation Laboratory with a major involvement of faculty and students from many departments in an exciting and rewarding project of social consequence.

The Instrumentation Laboratory has recently been asked by the Urban Systems Laboratory to collaborate with them in responding to a novel dual mode transportation concept involving the CARS system with a line-haul automated highway link. This effort may involve a major consortium of academic staff and students together with full-time professional Instrumentation Laboratory staff and private industries.

The division of scientific technology looks forward in the ensuing year to an increase in this type of intercommunity activity to benefit the Laboratory, the campus, and the university as a whole.

Support for sponsored research in the Instrumentation Laboratory increased by less than 1 per cent during the 1968-1969 period as compared with the previous year, the current yearly rate being approximately 54 million dollars. Total personnel, including associated laboratories and industrial assistance, was at about 2,450 on April 1, showing a downward trend of just over 1.5 per cent within the last year.

Education for the full spectrum of students, from undergraduates through graduates and postgraduates concerned with bridging the gap between academic studies and professional practice, has continued to be a major concern of the Laboratory. This activity, as in past years, was made very effective by the long-established position of the Laboratory as an integral part of the Department of Aeronautics and Astronautics. During April, 1968, about 398 students ranging from freshmen to candidates for doctoral degrees were associated in some significant way with the Laboratory. During the same month 77 members of the Laboratory staff were enrolled as Special Students at M.I.T. and 125 others were taking courses at outside schools. During the year 39 students carried out thesis work in the Laboratory under the supervision of faculty members and staff engineers. Of these students, 19 accomplished research at the doctoral level, 18 worked on Master's theses, and two concerned themselves with Bachelor's theses. A total of 24 degrees was granted at the June commencement to members of these groups.

In addition to providing facilities and teaching help for regular academic activities, the Laboratory employed 157 students in part-time work during April, a typical month.

Classification of reports and equipment produced by the Laboratory is involved in about 25 of the 46 existing contracts. It is usual for these



## DEPARTMENT OF CHEMICAL ENGINEERING

contracts to contain provisions allowing access to pertinent restricted information and specifying certain limited categories of data and design results that must be subject to security regulations. In practice, classification has interfered very little with educational activities of the Laboratory. For example, out of 11 theses accepted during a typical period between July and December, 1968, none were classified. Among Laboratory reports issued during the last six months of 1968, a representative sample numbered 104, of which 37 were classified, 17 as secret and 20 as confidential. The total number of pages involved was 15,821, of which 1.8 per cent were classified. Considering both the Laboratory reports and academic writing of some 17,329 pages, classification was involved for only 1.5 per cent. As a matter of general policy, all classified material is reviewed at intervals and cleared as soon as this action is possible.

Faculty members of the Department of Aeronautics and Astronautics have continued to provide general direction for Laboratory activities and to incorporate information and experience derived from developments of advanced technology into the body of engineering education. Institute Professor Emeritus Draper continued to serve as the Laboratory Director, with Professor Wrigley as Educational Director. Department faculty members associated with Professor Wrigley in academic activities included Professors Deyst, Halfman, Harrington, Hollister, Li, Markey, McKay, Meiry, Mueller, Potter, Vander Velde, Whitaker and Young. From the Laboratory staff, Dr. Richard H. Battin and Dr. Robert G. Stern served as Lecturers, taking responsibility for teaching subjects in aeronautics and astronautics. Roger B. Woodbury, Forrest E. Houston and Ralph R. Ragan continued to serve as Deputy Directors, with Joshua B. Feldman as Executive Officer.

RENE H. MILLER

## DEPARTMENT OF CHEMICAL ENGINEERING

The past year was one of extraordinary activity for the Department. Plans for a new building were announced; an important new endowed professorship was established; a new Department Head was appointed; our students took an active leadership role in new constructive action to improve the Department and the Institute; and research activity continued at a high level, particularly in biomedical and environmental engineering, in water desalination, and in surface phenomena.

### FACILITIES

The Department's long-standing need for a new building has reached the critical stage of decision. Our needs are threefold: (1) better facilities to

accommodate our current teaching and research activities, some of which place more stringent demands on facilities than has been the case in the past; (2) the need to bring the activities of the Department together in a single building, instead of in the three separate locations we now use; and (3) the need for additional space to house adequately our present staff and students and to permit a desired modest expansion in the next decade.

Because of the long lead time required in getting a new building, we are continuing to make badly needed changes in existing facilities. Building 43 is being air-conditioned to make it usable for research all year and to accommodate the types of equipment now being used there. Studies are in progress on modifications required in Building 31 to house the increasing work there in environmental engineering.

The Department has ordered an IBM 1130 system to be installed in Building 12 for hands-on operation; it will be freely available to students and staff for teaching and research. This will be supplemental to the central computing facilities, which will continue to be used for major research computation, as at present. Our computer needs will be reviewed at the end of one year's experience and modified accordingly. The new facility will be financed by a grant from the Institute and by industrial grants, primarily one from the Shell Foundation.

Perhaps this is an appropriate place to acknowledge the industrial grants, which have proved vital in our efforts to meet the needs of students for contemporary research facilities.

#### ENDOWED PROFESSORSHIPS

During the last four years, the Department has obtained three endowed professorships. The first of these was the Lamot du Pont Professorship in Chemical Engineering which was given by the du Pont family in memory of Lamot du Pont. The second was the Carbon P. Dubbs Professorship given by the family of Carbon P. Dubbs, and this year we received the Warren K. Lewis Professorship in Chemical Engineering as a gift of the alumni of the Department.

The endowed professorships are of great value to the Department. The income from the endowments permits the Department to give recognition to outstanding members of its faculty, to bring distinguished visiting professors from industry and from other schools, and to have flexibility in the development of its younger staff.

We are particularly pleased with the professorship recognizing Dr. Lewis' important contributions to the Department and to the profession. We appreciate the generosity of our alumni in endowing this chair. Year after year, the Course x alumni have been leaders in their contributions to the Institute. A number of them have served on the M.I.T. Corporation

and on the Visiting Committees for the Department of Chemical Engineering and for various other departments at the Institute.

During the past year, three of our graduates were elected to membership in the National Academy of Engineering, bringing the total of our department alumni in this organization to 10. The Course x alumni are a distinguished group, of which the Department is very proud.

#### FACULTY

Professor Edwin R. Gilliland became the first Warren K. Lewis Professor of Chemical Engineering in March. This is fitting recognition for the enormous contribution which Professor Gilliland has made to the Department. He has been Head of the Department for 12 of the last 18 years. This was a period of rapid change in curriculum and research. New graduate and undergraduate subjects were introduced, notably in the transport processes, catalysis and applied kinetics, surface chemistry and physics, materials, and project laboratories. There was a substantial increase in sponsored research, with new programs in biomedical engineering, water desalination, membranes, catalysis, transport in micro-porous media, and plasma chemistry.

The Department benefited from many visiting staff from all over the world during this period. The Ford postdoctoral program also made it possible for many young staff members to train in the Department for teaching positions at other schools. Three endowed professorships were established during his tenure.

We are all grateful for his many years of devoted leadership and are proud that it was possible to honor him with a new professorship.

Professor Raymond F. Baddour became Head of the Department in March, the fifth since Chemical Engineering was made a separate Department in 1920.

Samuel W. Bodman III was promoted from Assistant to Associate Professor.

The following new Assistant Professors were appointed: Clark K. Colton, F. Richard Cottrell, Hugh B. Hales, and Robert H. Mayer.

In addition, K. Sommasundra Rao was a Visiting Assistant Professor from the Birla Institute of Technology and Science (BITS) in Pilani, India.

The Department was fortunate in having Professor Geoffrey D. Parfitt, of the University of Nottingham, as the Visiting Carbon P. Dubbs Professor during the fall term of 1968. Professor Parfitt gave the subject on surface and colloidal chemistry and worked with our graduate students in this area.

The Department notes with regret that Thomas K. Sherwood, Lamot du Pont Professor of Chemical Engineering, will reach retirement age

at the end of the current year. He has been a leader in the Department and in the Institute for many years and he has made outstanding contributions in his teaching, in his research work, in his publications, in his development of students and young faculty, and in his contributions to the profession and to the government. He has received many awards and honors including membership in the National Academy of Sciences and the National Academy of Engineering, but his colleagues will remember him best for his friendly assistance, for his contagious enthusiasm for challenging engineering problems, and for his unique and stimulating suggestions and solutions. We all can trace a good deal of our basic understanding of chemical engineering phenomena to his insight. We are pleased that he will continue to be with the Department during the fall term of 1969.

Assistant Professor Charles W. Selvidge resigned to accept a position with Universal Oil Products Company. Professor Selvidge was director of the Bound Brook Station of the School of Chemical Engineering Practice for the last two years, and the Department would like to acknowledge his contributions to the successful operation of the Practice School and to wish him well in his new career.

#### STAFF ACTIVITIES

Professor Baddour served as co-chairman of a study group to assess the current status and opportunities for research in the area of surfaces and surface phenomena. This study was sponsored by the Center for Materials Science and Engineering. He was also an elected member of the Committee on Educational Policy.

Professor P. L. Thibaut Brian served as a member of the Committee on Research of the American Institute of Chemical Engineers, as a member of the visiting committee of the Chemical Engineering Department of Lehigh University, and as the Engineering School representative on the M.I.T. Committee on Educational Policy, where he served as chairman of the Task Force on Chemistry.

Professor Gilliland served as a member of the Board of Visitors for the Department of Chemistry of Tufts University, as a member of the Industrial and Professional Advisory Council of Pennsylvania State University, and as a consulting professor to the College of Engineering of Louisiana State University. He was chairman of the Engineering Section and chairman also of Division III of the National Academy of Sciences and a member of the Finance Committee of the Academy. He was on the Editorial Board of the *A.I.Ch.E. Journal*. He served as a member of the Management Advisory Council of the Oak Ridge National Laboratory of the Atomic Energy Commission and as a consult-

ant to the President's Science Advisory Committee. He was chairman of the canvassing committee of the A.C.S. (American Chemical Society) Award for Creative Invention. He served as a member of the Institute's panel to review the Special Laboratories.

Professor Hoyt C. Hottel was chairman of the American Flame Committee, a subsidiary of the International Flame Foundation, and a member of the National Academy of Sciences — National Research Council Committee on Fire Research.

Professor Herman P. Meissner served as a member of the Office of Saline Water Evaluation Committee for Ion Absorption Processes.

Professor Edward W. Merrill was a member of the Contract Review Committee and consultant to the Director of the National Institute of Arthritis and Metabolic Diseases. He served as consultant to the Massachusetts General Hospital, the Beth Israel Hospital, and the Peter Bent Brigham Hospital. He was a trustee of the Buckingham School.

Professor Harold S. Mickley continued as Director of the M.I.T. Center for Advanced Engineering Study. He was also a member of the Special Lectures Committee and the Education and Accreditation Committee of the American Institute of Chemical Engineers (A.I.Ch.E.).

Professor Robert C. Reid was Council Member of the American Institute of Chemical Engineers and Technical Program Chairman of the Montreal Tripartite Meeting for A.I.Ch.E.

Professor Charles N. Satterfield was a member of the Editorial Board of *Industrial and Engineering Chemistry*.

Professor Sherwood was chairman of the National Research Council Committee on Air Quality Management and a member of the Editorial Advisory Board of *Industrial and Engineering Chemistry*.

Professor J. Edward Vivian was a member of the American Chemical Society Award Subcommittee.

Professor Glenn C. Williams spent his sabbatical leave as Visiting Professor and consultant to the University of Puerto Rico. He was vice president, a director, and a member of the Papers Committee of the Combustion Institute and a consultant to the U.S. Office of Education.

Professor Lawrence B. Evans was a member of the American Institute of Chemical Engineers' Projects Committee.

Professor Allan S. Hoffman was a member of the Editorial Advisory Board of *Polymer Engineering and Science* and of the A.I.Ch.E. Water Committee. He was also session chairman at one meeting of the American Chemical Society and co-chairman of another, both on aspects of polymer chemistry.

Professor Adel F. Sarofim was Technical Secretary of the American

Flame Research Committee and a member of the Editorial Board of the Solar Energy Society.

Professor Michael Modell was chairman of the Catalysis Club of New England.

#### STUDENTS

During the past year, our students have been especially active in constructively promoting improvements at the Institute and in the Department. John B. L. Harkness, a doctoral candidate, assumed the leadership in the Graduate Student Council, an Institute-wide organization. Richard G. Donnelly, also a doctoral candidate, was instrumental in organizing a Department Graduate Student Committee. We have worked together effectively on a wide range of projects, from better interactions between staff and students to improving our subject content and offerings.

Working with our undergraduates has been equally rewarding. Under the leadership of Bruce K. Hamilton, a Five-Year Student Council has been formed to help in counseling freshmen, planning more effective undergraduate laboratories and seminars, improving the undergraduates' understanding of the chemical engineering profession and the constructive role it plays in society, and many other topics of urgent interest to students.

It has been most impressive to work with these students. Their enthusiasm is contagious and their energy awesome. But most important, they are sincerely eager to give generously of their time and energy towards working on the problems they see. They will find in us ready partners in their efforts.

#### STUDENT AWARDS

Mr. Hamilton received the Hunneman Prize awarded annually to a senior for outstanding originality in chemical engineering. Stanley M. Goldin was awarded the Haslam Cup for outstanding professional promise. David C. Silverman was awarded the Alpha Chi Sigma Prize in recognition of distinguished scholastic achievement, originality, and breadth of interest in chemistry and closely related fields. Peter J. Drivas won the American Institute of Chemists Award for outstanding promise through demonstrated scholarship and leadership for advancing the professional aspects of the scientific community.

#### DEGREES

For the period July 1, 1968, to June 30, 1969, the Department awarded 24 Bachelor's degrees, 32 Master's degrees, two Chemical Engineer degrees, and 16 doctoral degrees.

**SUBJECTS AND RESEARCH**

The curriculum development that has been under way for several years is continuing with the introduction of new subjects, and with the development of new texts for those begun in the last few years. Professor Brian continued his development of the introductory subject on staged cascades, and Professor Kenneth A. Smith continued his work on the transport processes. Professor Bodman introduced a new graduate subject on transport processes; Professor Meissner introduced a new graduate subject in applied chemistry; and Professors Max C. Deibert and Satterfield introduced a revised applied kinetics subject.

The Department has inaugurated a new program for the simultaneous Bachelor's and Master's degree in Chemical Engineering. The combined program allows the student to plan his subject sequence most effectively and enables him to do a single, more extensive thesis for both degrees or to fulfill the thesis requirements for both degrees by attending the School of Chemical Engineering Practice. The Department believes this program will offer an advantage to those students who make a decision early to attend the graduate school and whose records are satisfactory for graduate work. It enables the student to plan with his faculty advisor a program that is most effective for the student's interest and it allows the student who attends the Practice School to take increased subject work at the Institute. We believe this program will be attractive to many of our students.

Research activities within the Department have continued at a high level, as may be noted from the summaries below. Especially notable will be the staff's major activities in biomedical research, environmental engineering, particularly pollution problems, and surface phenomena, with considerable emphasis on catalysis.

**RESEARCH**

**COMBUSTION AND RADIATIVE HEAT TRANSFER**

Research on kinetics, heat transfer, and flow in combustion processes has continued in the Fuels Research Laboratory under the guidance of Professors Jack B. Howard, James J. Noble, Hottel, and Sarofim.

Control of the formation of soot in flames is of importance in many applications. Soot may be sometimes desirable, as in augmenting heat transfer in high-temperature process furnaces, and at other times undesirable as a pollutant or a source of thermal punishment to the liners of jet combustion engines. Towards the long-range goal of predicting the concentrations of soot formed under different conditions, the mechanisms

by which short-chain hydrocarbons produce soot particles 50Å to 800Å in diameter is being studied, with particular emphasis on determining the role of ions in the nucleation of soot particles and on the effect of interparticle electrostatic forces on growth and agglomeration. The size and the electric charge of carbon particles at different stages of formation are being measured in a flat flame of propane and oxygen. A quartz microprobe is being used for sampling, and the carbon particles are analyzed using an electric precipitator and an electron microscope.

A problem of continuing interest is the modeling of the propagation of line fires through brush or other combustible solids. Many of the studies of model systems in this and other laboratories have used cellulosic materials as a fuel, and the interpretation of the results has been hindered by the difficulty of describing the pyrolysis kinetics and the thermal properties in the fuel bed. In order to overcome these difficulties, subliming solids have been selected for study. Measurements of the propagation rates of line fires are in progress and will be used to evaluate the contributions of the different modes of heat transfer, particularly conduction near the fire front, to the propagation rate.

Utility boilers and large process furnaces contribute approximately 40 per cent of the nitrogen oxide pollutants discharged into the atmosphere. Nearly all these oxides are formed in small high-temperature zones within the combustion chamber of the furnaces, and it is therefore possible greatly to reduce the undesirable emission by modification of the operation and/or design of the combustion equipment. In making changes, however, care must be taken that the nitrogen oxides not be replaced by other pollutants such as unburnt CO or coked particles. Mathematical models of the kinetics, flow, and heat transfer in the furnace are being developed which show potential of providing a useful and inexpensive method of evaluating different changes in the operation and design of furnaces. The models are now being extended to more realistic conditions. A complementary experimental study of the rate of nitric oxide formation in a flat-flame burner is being used to determine the reliability of the kinetics in the temperature and concentration ranges of interest.

The incineration of solids involves a complex interaction of heat and mass transfer, pyrolysis, solid and gas phase oxidations, processes which have all been studied separately. A mathematical model of incineration based on available estimates of the kinetics of the basic processes involved has been developed and used to evaluate existing and novel incinerator schemes. Complementary experimental and theoretical studies of the combustion of a fuel bed are planned under a grant from the Environmental Control Administration of the Public Health Service.



Surfaces with special absorptive or emissive properties are of value for solar energy collection and other applications. Initial success in the Fuels Laboratory of preparing surfaces which absorbed solar energy selectively, by deposition of copper oxide particles on polished aluminum, led to a more fundamental study of the radiative properties of particulate suspensions. Models have been developed that will predict the radiative properties of pigment dispersions entirely from theory, starting with the Mie equations for single scatter and then allowing for multiple scatter. During the past year, theoretical predictions of the reflectance and transmittance of polystyrene lattices were shown to agree exactly with experimental values, provided that the minimum distance of separation between particles was greater than one-third the wavelength of interest. The scattering efficiency of a particle was found to fall below its theoretical value at smaller distances of separation. A correlation to predict the reduction in scatter due to interference between particles was developed. An important practical consequence of the results is that there is a concentration above which increasing the concentration of white pigments decreases rather than increases the surface reflectance.

Little quantitative understanding of the factors controlling the quality of the glass from a glass-tank furnace is presently available. The glass ingredients are melted and refined in open-hearth furnaces which may be a hundred feet long. The energy is supplied by burners fired across the surface of the glass melt, and mixing is entirely by the natural convection currents within the melt. Because of the difficulty and cost of experimenting on full-scale units, mathematical and experimental models of glass furnace operation are being set up. The heat transfer from the combustion gases to the melt is first calculated to obtain the flux boundary conditions at the top surface of the melt. The convection currents within the melt are then obtained by solution of the coupled flow and energy equations. The preliminary results from the studies are consistent with the limited data available on full-scale units. The model is being used to derive conclusions of practical interest on the effect of insulation of the bottom and sides of a glass tank. Mixing in the tank is promoted by insulation of the bottom but is decreased by insulation of the sides. In the course of these studies some complex numerical problems on the solution of the Xavier-Stokes equations and the inclusion of radiation in the energy equation were encountered. These have become the subjects of complementary studies described below.

Work has continued on the development of improved methods for the solution of radiant transfer problems by the zone method. A computer program is now available to evaluate the exchange integrals required for problems in Cartesian geometries involving gray absorbing-emitting

fluids. A new finite difference scheme has been tested which may be used to extend the usefulness of the calculational procedure to the non-linear problem of conduction-radiation interaction. This numerical scheme would appear to be highly efficient in the general case of intermediate optical thickness.

Research has continued on finite-difference computation of enclosed natural convection flows. Prime focus has been on the buoyantly driven flow of a fluid confined in a two-dimensional vertical slat, the sides of which are maintained at different temperatures. It is known experimentally that for sufficiently large height-to-width ratios and temperature differences, secondary and tertiary flows will develop between the vertical walls of the enclosure. While computer storage requirements have prevented numerical simulation in this regime, anomalous results have been obtained for computations with height-to-width ratios of only four to one. A companion experimental program has verified several of the features of the flow pattern predicted by the computer for this case.

#### CATALYSIS, APPLIED KINETICS, AND REACTOR TECHNOLOGY

During the past few years molecular sieve catalysts have become of major importance in the processing of hydrocarbons. The diffusional characteristics of product and reactant molecules in the tiny pores of these materials can have a major effect on the course of the reaction. Studies of diffusion in molecular sieves and in their catalytic derivatives have been under way in our laboratories for several years. During the past year, Professor Satterfield and James R. Katzer have been studying the counter-diffusion of hydrocarbons in forms of type Y zeolite, which has pore openings of about 9 Angstroms and is of considerable industrial importance.

The experimental procedure involves first saturating the open pore-structure of the zeolite with a liquid hydrocarbon. The saturated zeolite is then placed in a second liquid, and the rate of diffusion is followed by analyzing samples removed from the bulk mixture. Zeolites have been studied in the form of single crystals, approximately 1 micron in size, and by this procedure diffusion coefficients of about  $10^{-11}$  cm<sup>2</sup>/sec and lower can be measured. With SK-500, a commercial ion-exchanged-type Y zeolite, the diffusion rate of cumene into benzene is so great that an accurate determination of the diffusion coefficient was not possible. In contrast, the diffusion rate of cumene from the original sodium Y zeolite in benzene is much slower, and the associated initial effective diffusion coefficient,  $D_{eff}$ , at 25°C equals  $1.25 \times 10^{-13}$  cm<sup>2</sup>/sec. The activation energy associated with this desorptive diffusion process is 17.4 kcal per gram mole. This value is essentially the same as the heat of adsorption of

cumene on sodium Y zeolite, indicating that the rate of desorption itself probably is very important in the desorptive diffusion process. The effect of the nature of the cation upon the diffusion coefficient was studied by measurements with larger molecules, for example, 1-methyl naphthalene or 2-ethyl naphthalene, and by studying other forms of the sodium Y zeolite, namely those obtained by ion-exchanging the sodium to replace it by the  $\text{NH}_4^+$ ,  $\text{Ca}^{++}$ , or the  $\text{Ce}^{+++}$  cation and activating the zeolite by a carefully controlled heating procedure. The diffusion coefficients under initial conditions for 1-methyl naphthalene into cumene at  $0^\circ\text{C}$  are as follows: sodium Y,  $3.6 \times 10^{-14}$ ; calcium Y,  $1.8 \times 10^{-13}$ ; SK-500,  $3.1 \times 10^{-13}$ ; cerium Y,  $1.1 \times 10^{-12}$ ; and ammonium Y,  $2.0 \times 10^{-12}$   $\text{cm}^2/\text{sec}$ .

It is known that the nature of the cation can affect the apparent pore size of a zeolite slightly, but the marked effect on the diffusion coefficient is noteworthy. The extreme values vary by a factor of almost 200. This strongly implies that reports of the effect of the nature of various cations on the catalytic activity of molecular sieves may represent, in many cases, a physical effect rather than a variation in intrinsic chemical reactivity. Impurities present in the organic compound being studied, and the zeolite activation procedure, may each also have a considerable influence upon the diffusion rate observed. The counterdiffusion of molecules of this size occurs freely, although not independently, within the type Y zeolite pore structure, as was shown by the fact that the same equilibrium point was reached for several different starting points. The fact that molecular interaction does occur during the counterdiffusion, however, was illustrated by varying the nature of the organic liquid outside the zeolite and observing the substantial effect on the diffusion coefficient. When the higher diffusion coefficients are observed, as in ammonium Y and cerium Y, the diffusion process follows Fick's law closely over at least the first 60 per cent or more of the approach to equilibrium. With more restricted diffusion, however, the effective diffusion coefficient drops off substantially with the degree of approach to equilibrium. On sodium Y, for example, the effective diffusion coefficient drops from an initial value of  $3.6 \times 10^{-14}$   $\text{cm}^2/\text{sec}$  to a point value of  $1.5 \times 10^{-14}$   $\text{cm}^2/\text{sec}$  at 60 per cent of equilibrium.

In close association with the above work, Professor Satterfield and Chon S. Cheng are studying the effect of molecular size and shape on the rate of diffusion of liquid hydrocarbons in sodium Y zeolite. In the absence of a counterdiffusing molecule, such as occurs when a hydrocarbon is contacted with a previously evacuated molecular sieve, the diffusion coefficient is much greater. For example, for 1-methyl naphthalene in sodium Y, the initial diffusion coefficient is approximately 20,000 times that observed when the same hydrocarbon is diffusing into cumene.

Studies with a variety of substituted benzenes are revealing the great sensitivity of diffusion coefficients to the critical molecular diameter of the diffusing molecules. For substances having relatively small critical molecular diameters, and hence high diffusion coefficients, the activation energies for diffusion are substantially lower than those observed for larger molecules, which would be expected in view of the restricting influence of the pore walls.

In conjunction with a study of hetero-homogeneous catalysis, Professor Satterfield and Douglas H. Cortez have obtained new data on mass transfer rates to woven screen catalysts, such as those used in ammonia oxidation, and they have examined the previous literature critically. This analysis shows that the heat and mass transfer characteristics for these systems may be more conveniently correlated by expressing  $j$  factors as a function of the Reynolds number based on the wire diameter rather than the hydraulic radius. The transport characteristics of screens and infinite cylinders are very similar. Literature data on heat transfer to screens are probably in error at low Reynolds numbers due to neglect of longitudinal heat conduction. The number of screens and degree of screen separation seem to have little significant effect on mass transfer rates.

The effect of certain critical system parameters on the rates of reaction in trickle-bed reactors have been under study for several years by Professors Sherwood and Satterfield. The current study, with Peter F. Way, is aimed at determining the relationships between the intrinsic kinetics of a gas phase reaction and the same reaction as carried out in a gas-liquid environment in a trickle-bed reactor. A further objective is to investigate the effect of different liquid phases on the kinetics of a reaction in a gas-liquid environment. This is to evaluate the possibility of obtaining better temperature control in a packed-bed reactor by removing heat via a liquid phase, consisting of an inert liquid or a product of the reaction. The model reaction chosen for these studies is the isomerization of cyclopropane to propylene on a silica-gel cracking catalyst. The liquid phases to be studied are undecane, ortho-xylene and ethylene glycol. The trickle-bed studies are being carried out in a 1-inch by 18-inch reactor, and a second reactor utilizing finely ground catalyst is being used to determine the intrinsic kinetics.

Professor Reid has been active in research in cryogenic chemistry with emphasis on elucidating the mechanism of reactions between hydrogen atoms and solid olefin films at 77°K.

In the past year, several important equipment modifications have been effected. Reactions may now be carried out at constant hydrogen pressure in a sensitive ESR (electron spin resonance) cavity. Hydrogen atoms

previously generated by a 2,450 MHz (megahertz) microwave discharge have now, in addition, been generated on tungsten filaments heated to temperatures up to 2,200°K. Constant concentrations of hydrogen atoms during the course of the reaction have been obtained and monitored using an electron spin resonance spectrometer.

In this hydrogen atom-olefin gas solid system, in which simultaneous diffusion and chemical reaction occur, experimental variables such as film thickness and hydrogen atom concentration have been studied to assess the relative importance of two competing reaction mechanisms: hydrogen atom penetration and reaction throughout the *bulk*; and diffusion of olefin and radical species and reaction with hydrogen atoms at the *surface*. Experimental rates of reaction are in agreement with reaction rates predicted by a "bulk" reaction model.

Professors Baddour and Modell are continuing their study of fundamental surface phenomena which occur in catalysis by metals. The objective of this program is to develop a general method of determining the mechanisms of gas-phase, metal-catalyzed reactions. A method has been proposed, which consists of measuring simultaneously the overall reaction rate and the concentrations of surface intermediates as functions of temperature and reactant pressures. Infrared spectroscopy is used to measure surface concentrations. Postulated mechanisms can then be tested directly by comparing experimental and theoretical forms of the rate, expressed in terms of surface concentrations.

In an experimental program initiated in 1963, simultaneous infrared and kinetic measurements were made for CO oxidation on silica-supported palladium catalysts. For the CO-Pd system, two types of surface species were identified by infrared spectroscopy. Palladium-oxygen absorption bands were not observed because the background absorption of the silica support is intense in the region where Pd-O<sub>2</sub> bands are believed to occur. The results indicated clearly the inadequacy of the conventional kinetic approach and the value of simultaneous measurements. However, the experiments were not sufficient to identify unequivocally the reaction mechanism. Two essential pieces of data were lacking: spectroscopic observation of the palladium-oxygen species, and extinction coefficients of the surface species. The investigations now in progress are aimed at developing methods for obtaining the additional data.

A program is in progress for obtaining absolute values of surface concentrations by measuring the relative extinction coefficients of adsorbed species. The method essentially involves relating the increase in total amount of gas adsorbed during sequential dosing of a catalyst with adsorbate to the relative increase in integral absorbance of the infrared bands. When the extinction coefficients have been determined, simul-

taneous measurements of kinetics and spectra will be made over wide ranges of surface coverage. In this investigation, the catalysts are silica-supported metals of the type previously used for infrared transmission spectroscopy of adsorbed species.

A second set of experiments, under the supervision of Professors Baddour and Modell, is in progress to develop general techniques for observing infrared absorption bands of all surface species. The conventional infrared method involves transmission spectroscopy in which small particles of metal (50Å) are supported on finely divided silica or alumina (100Å). Large regions of the infrared are obscured by the intense absorption of these supports. Thus, palladium-oxygen bonds have not been observed because they are believed to occur in the region of the silica continuum. In an effort to surmount the limitations of conventional transmission spectroscopy, an attempt is being made to observe reflection spectra of unsupported metals. An interferometer is being used to measure the relatively weak signals. It was estimated that with 80 reflections of the infrared beam between metal foils, it should be possible to measure concentrations of surface species quantitatively down to 1 per cent of a monolayer in the range of 250 to 2,500  $\text{cm}^{-1}$ . To date, the apparatus has been assembled and preliminary experiments are in progress. Tests were made to determine the sensitivity of the interferometer and the reflectivity of the metal foils. The first tests with carbon monoxide adsorbed on palladium foils have been made recently, and the results are very encouraging; we believe that we are observing absorption bands which correspond to known CO surface species. The successful development of this technique would significantly enhance the applicability of infrared spectroscopy in catalytic studies and would permit direct observation of phenomena which have been the subject of much speculation and conjecture.

A third study was initiated recently with the objective of measuring and correlating the rates of adsorption and desorption of gases on transition metals. There have been very few attempts made to correlate rates of adsorption and desorption quantitatively. Within recent years, it has become evident that these processes are not simple; for a given gas and a given metal, many surface species are known to coexist. The techniques we are developing to study mechanisms of catalyzed reactions are directly applicable to the study of adsorption and desorption processes. Thus, by observing overall rate of adsorption and infrared spectrum of the surface, it should be possible to measure the adsorption rates of each surface species. Such experiments are planned for a given gas on a series of metals. In this manner, it is hoped that the rate of adsorption of each type of surface species can be observed on different metals. An attempt will be

made to correlate these rates with electronic and geometric properties of the metals.

Professors Baddour and Modell are also continuing the study of the effect of visible and ultraviolet light on gas-phase, metal-catalyzed reactions. In earlier studies, it was demonstrated that light has an appreciable effect on the rate of carbon monoxide oxidation over a palladium catalyst. The effect was attributed to electronic excitation of a surface-adsorbate bond which, in turn, results in a change in the rate of desorption of surface species. The objectives of a study recently initiated are to determine the extent to which other systems can be similarly affected, and to investigate more thoroughly the mechanism of the photocatalysis. Monochromatic light of variable frequency will be employed to determine which frequencies are photo-active. The study would provide information on the electronic structure of the bond between the absorbed molecules and the surface atoms. This information can be used to interpret and predict the behavior of metal catalysts.

Professors Baddour and Deibert have continued to investigate the promoting influence of interphase electronic interaction between the catalyst and the support. The catalyst under investigation is nickel supported on germanium. In this system the magnitude of the Volta potential difference and specific interphase charge transfer can be predicted using the Schottky analysis of metal-semiconductor contact. The variations in these parameters, brought about by changes in the type and concentration of impurities in the germanium, have been shown to influence the kinetics for formic acid decomposition on the supported nickel. Additional measurements are being made to determine if the kinetics of ethylene hydrogenation on the nickel catalyst is similarly influenced by support-catalyst electronic interaction effects. Measurements of total surface area and specific nickel surface area are being utilized to provide a more complete characterization of the nickel-germanium catalyst system. As a part of this research the thermal stability and adsorptive properties of high surface area, vacuum crushed germanium have been determined. Germanium powders with surface areas on the order of 100 square centimeters per gram suffer about 10 per cent loss in area by sintering under vacuum at 300°C for one hour. Neither the freshly crushed nor the sintered germanium powder absorbs measurable quantities of carbon monoxide.

An investigation of the contacting of the fluid and the solid in a packed bed catalytic reactor has been made by Lee P. McMaster and Professor Gilliland.

In the theoretical portion of the study, a number of models were analyzed for given residence time distribution. These models considered

the variation of the residence times, the distribution of porosities, and the dispersion. A generalized model has been proposed for predicting the maximum and minimum levels of conversion in a reactor of given residence time distribution of arbitrary reaction kinetics. An experimental program was executed to investigate the validity of the proposed models. The object of the experimental work was to measure the conversion of a chemical reaction and the residence time distribution in the external field simultaneously. The reaction system was the acid-catalyzed reversible esterification/hydrolysis of methanol and acetic acid. This reaction is catalyzed heterogeneously by an ion exchange resin in the H form. A modified resin was prepared in an attempt to obtain large particles which yield a larger distribution of residence times, but which are active only on an outside surface layer so that diffusional resistances within the pores of the catalyst are negligible. The particles were approximately 3 mm in diameter.

The equipment used for the packed bed experiments consisted of a reactor section of variable length and packing arrangement, and of a tracer injection and recording apparatus. A du Pont dye, Luxol Fast Blue MBSN, which had been converted to the acid form, was used as a tracer. This dye is restricted from entering the ion exchange resin particles due to the combined influence of the Donnan potential and the molecular sieve effect for large anions.

The performance of the long reactors was near to ideal plug flow. In most cases the experimental results for the shorter reactor were in reasonable agreement with several of the models, and those involving the distribution of porosities came the closest.

The oxidation of hydrogen chloride is being studied by Daniel L. Flamm under the supervision of Professors Baddour and Gilliland in a radiofrequency discharge (about 6 MHz), using reactors designed to provide improved field properties. A range of engineering parameters have been studied: pressure, flow rate, power level, feed composition, and reactor geometry. Data on chemical yield, plasma voltage drop, plasma resistance, and effective capacitance to electrodes were obtained as a function of power and residence time for reactors of varying aspect.

A preliminary interpretation of the data indicates that the discharge may be dominated by negative chlorine ions and that maximum conversion of HCl is limited by the detailed quenching of species in thermodynamic equilibrium near the gas temperature.

An investigation of the hydrogenation of ethylene on a copper-impregnated catalyst to test the effectiveness of the gas-solid contacting in a fluidized bed has been made by Christian W. Knudsen under the supervision of Professor Gilliland. The fluidized bed reactor was 2 inches in



diameter and 5 feet long. The range of variables investigated were gas superficial velocities of 0.1 to 1.6 feet per second (fps), bed heights from 0.6 to 2.8-foot catalyst activities for  $0.6$  to  $8.9 \times 10^{-5}$  (g mol/g sec atm) and catalyst particle sizes from 52 to 120 microns.

Essentially complete conversion was obtained for gas velocities between 0.1 and 0.2 fps, indicating that no portion of the gas completely bypasses all of the catalyst. At higher velocities the ethylene conversions were always less than those predicted for idealized plug flow. Under some conditions conversions substantially below those for a completely mixed reactor were obtained.

The contacting efficiency was found to be substantially constant with increasing gas velocity and with increasing bed depths. With narrow size distributions, large-size particles were more effective than small-size particles. For a given particle size, the reactor efficiency was well correlated by a dimensionless reaction group over a wide range of gas velocity catalyst amount and catalyst activity. The experimental results were compared with a number of mathematical models of fluidized bed behavior.

#### CHEMISTRY AND PHYSICS OF POLYMERS AND SURFACES

The investigation of viscoelastic behavior of biocolloid-like complex coacervate systems continues under the supervision of Professor Hoffman. Reaction products of oppositely charged polyelectrolytes of different charge frequency along the backbone are being studied. The swelling of such materials in salt solutions, such as NaCl, NaBr, and NaI, reveals the increased significance of ion-binding of the halide ion to the quaternary polyion in the series iodide, bromide, and chloride. The salt and water contents of swollen films are being measured in these solutions. Stress-strain behavior of the coacervates immersed in these same salt solutions has led to attempts to correlate and predict the modulus as well as the viscoelastic response based on the swelling data. Measurement of swelling data in these systems will also permit a revision and refinement of the equilibrium thermodynamic theory of complex coacervation.

The investigation of the unusual temporary effects of intense radiation fields on the mechanical properties of polymers is continuing under the supervision of Professors Gilliland and Hoffman. The study of the accelerated creep rate of polystyrene samples in a 3-MeV electron beam resulted in the hypothesis of a mechanism based on temporary accumulation of gases within the polymer during irradiation. Extension of the work to polymethyl methacrylate (PMMA) has led to a revised mechanism, wherein the act of gas generation supplies the necessary energy and

local free volume to a particular chain segment. Then, when the radiation is terminated, these gases diffuse to local voids or fissures where they are ineffective in accelerating creep further. This mechanism has been tested with polycarbonate polymer films. It has been found that the critical factor governing the rate of creep during irradiation is the state of strain of the polymer, particularly at higher stresses or higher radiation intensities. At very low stresses or low intensities, the total accumulated dose appears to be the most important factor. A modified Eyring relaxation flow theory correlates most of these data.

Professor Hoffman has been supervising a continuing series of investigations into the modification of the surface energies of low surface-energy polymer substrates. High-energy radiation has been used to initiate graft polymerization of various ionized and nonionized hydrophilic monomers to the surface of polyamide and polyester films. The increase in surface energy has been estimated by measuring the change in contact angle for various liquids on these treated surfaces. The contact angles have been interpreted in quantitative terms by calculating the various contributions to the interfacial free energy of the liquid-polymer interface. These results are pertinent to static dissipation, wetting, and dewetting on polymer films and fibers.

Professor Colton, as part of his doctoral thesis under the direction of Professors Smith, Merrill, and Evans, has investigated the permeability, to solutes of differing molecular weight and conformation, of cellophanes. He has quantitatively demonstrated the profound reduction of permeability that occurs when wet gel cellophane is dried by the commercial method (glycerol plasticization) and then re-equilibrated in water. To small molecules, such as sucrose, the permeability is reduced 50 per cent, but to larger molecules, such as insulin, the reduction is by a factor of 10 or more. It is believed that these studies may have a general applicability to any polymeric membrane regenerated from solution which depends on partial crystallization of the polymer chains to confer insolubility. Otherwise stated, the observations should lead to a new approach to nucleation and crystallization in polymers.

#### HEAT, MASS, AND MOMENTUM TRANSFER

Professors Merrill, Smith, Preetinder S. Virk, and Cottrell have, with the support of the Office of Naval Research, continued their studies of the Toms Phenomenon. This name refers to the experimental observation that, in turbulent flow, very dilute solutions of certain high molecular weight polymers may exhibit considerably less skin friction than does the solvent alone. Delineation of the overall phenomenon appears now to be reasonably complete, particularly with the refinement during the

past year of the maximum drag reduction asymptote concept. An understanding of the phenomenon is, however, not yet available, and recent efforts have focused upon the design and construction of apparatus capable of providing conceptual insight.

Since much of the information gathered to date indicates that effects are most pronounced in a region within 150 microns of the pipe wall, Gregory H. Keuroghlian has constructed an apparatus capable of investigating this region. A diffusion-controlled electrode reaction will be utilized, and fluctuations in reaction rate will be related to the turbulent spectrum in the region near the wall.

William B. Clarke is investigating polymeric effects. Nearly all of the available data were obtained with random-coiling molecules. Polyelectrolytes, however, can be changed from a rod-like conformation to a random-coiling conformation by appropriate changes in the ionic strength of the solvent. Thus, it will be possible to study conformational effects with a single molecular species.

Professors Brian and Vivian are continuing their research in simultaneous gas absorption and chemical reaction. One study is concerned with the influence of the mass transfer process involved in the absorption of a reactant gas on product selectivity for sequential chemical reactions occurring in the liquid phase. The experimental system chosen as an example of this interaction is chlorine addition to 1,7-octadiene dissolved in orthodichlorobenzene. A short wetted-wall column is used as the gas-liquid contacting device. There is evidence from the literature that the reaction rates are high enough to show a marked effect of the diffusional process in the liquid phase on the product distribution. The kinetics of the chlorine addition are known to be second order. Furthermore, batch experiments have been carried out which show that essentially only two products are produced. The wetted-wall apparatus has been designed to allow the pressure to be reduced from atmospheric pressure to decrease the contribution of the gas phase resistance to the mass transfer process. The experimental data on product distribution for chlorine addition to the diene are to be compared with theoretical results obtained from film theory and penetration theory models of the absorption process.

A second study is concerned with the effect of interfacial turbulence caused by surface tension gradients, known as the Marangoni effect, which may arise during the transfer of surface active solutes across the gas-liquid interface. The object is to measure and correlate the effect of this turbulence on the rate of mass transfer quantitatively. The rate of desorption of each of the following solutes from water into nitrogen is being measured at various solute concentrations and gas and liquid flow rates in a conventional short wetted-wall column; methyl chloride, ethyl

ether, triethylamine, and acetone. These solutes are all known to lower the surface tension of water and, in the case of the last three, have been found to produce surface instabilities in stagnant systems. The mass transfer resistance varies from almost total liquid phase control for methyl chloride to almost total gas phase control for acetone. Liquid and gas phase mass transfer resistances are being monitored by simultaneously measuring the rates of propylene desorption and of water evaporation, respectively. In this way the effect of the disturbance on the mass transfer resistance in each phase is readily determined.

Results indicate that a 1.7-fold enhancement in the liquid phase mass transfer coefficient is obtained when 0.05 wt. per cent ether is desorbed from water. This enhancement rises to nearly four-fold as the ether concentration is increased to 1.1 wt. per cent. The above enhancement is thus a strong function of the ether concentration but is found to be only a weak function of the liquid flow rate. Preliminary results indicate that the gas phase coefficients are affected only slightly by the disturbance. Visual confirmation of Marangoni instability, not usually observable in flow systems, has been obtained at low liquid flow rates.

Professors Brian and Bodman have continued their research activities in the field of heat transfer accompanied by a simultaneous, reversible chemical reaction. In particular, experimental results have been reported on the thermal conductivity of decomposing nitrogen dioxide over a wide range of temperatures and pressures. It is believed that these are the first thermal conductivity data ever reported where the rate of energy transport is limited by the rate of chemical reaction in the transport medium. The data have been interpreted successfully by a mathematical model that predicts the degree of enhancement in thermal conductivity caused by the presence of a chemical reaction. Moreover, it has been suggested that by applying this model to experimental data on the conductivity of an arbitrary, reversibly reacting gas, one has a very convenient means of estimating the chemical kinetic constants for the reactions involved. This technique is applicable when reactions of very short half-life (approximately 1 millisecond) are present. The same experimental apparatus has been utilized for measuring the thermal conductivity of carbon monoxide-hydrogen mixtures at pressures up to twice the mixture critical pressure. These results provide an excellent basis for evaluating the various estimation techniques for the conductivity of high-pressure gas mixtures.

Professor Reid has research under way in two areas of crystallization. In one study, seed crystals of KCl are being grown from aqueous solutions under controlled conditions of temperature, supersaturation, and impurity level. The rate of growth of various crystal planes is followed

by time-lapse motion pictures taken through a long objective lens microscope. One of the principal results of this study will be to extend the temperature range studied from 0°C to almost 100°C, a much wider range than studied previously. Lead and iron impurities in the parts-per-million range will be added, since preliminary experiments have shown that such impurities exert a profound effect on the rate of growth. Various theoretical models of crystal growth are being formulated to allow a comparison with experimental data.

The second area under study involves the effect of surface morphology and impurities on the rate of vaporization of specific faces of arsenic. Small, well-formed arsenic crystals are heated and vaporized into a vacuum. During vaporization, the macrosurface structure is studied with a microscope. Also, laser reflection patterns are monitored and the rate of evaporation of a given face determined with an interferometer. To accomplish all these measurements, the crystal is set in a furnace on a goniometer and exposed to the various instruments by rotation.

The crystallization research group meets bimonthly with a similar group from Tufts University to discuss new developments in crystal growth kinetics. Various outside speakers are also invited to address the group on such diverse areas as high pressure crystal growth, crystallization from aqueous solutions, and laser reflection techniques.

Professors Reid and Evans have completed an investigation of the thermal stratification phenomenon due to natural convection circulations in enclosed fluids. The study was composed of two parts. One part was an experimental study whereby a constant heat flux was applied to the sidewalls of a rectangular container filled with fluid and the resulting natural convection circulations were observed. These observations consisted of "streak" photographs of neutrally buoyant spheres immersed in the fluid from which streamlines could be obtained and temperatures measured using fine wire iron-constant and thermocouples. Particular emphasis was placed on the upper 20 per cent of the container, since it was in this region that least was known about the fluid mechanics. A theoretical study of the boundary layer equations was also carried out for the case of a constant wall heat flux and a linear temperature gradient in the core. The study was undertaken because it was known that such a linear gradient exists in the core for the case of the above-mentioned system and, therefore, some knowledge of the boundary layer temperature and velocity profiles were required to describe the system adequately.

It was found that the thermal stratification phenomenon could be described as a process involving boundary layer-core interactions. The wall heat flux caused warm boundary layer fluid to rise up the wall and

spread over the surface deflecting cooler fluid downward into the core, and thereby establishing a thermal gradient in the core. The amount of fluid which reaches the top and the temperature increase is in turn dependent on the core temperature gradient. A model was developed to predict this interaction for a wide range of system variables.

Another experimental investigation is being undertaken to determine the effect of the distribution of sidewall heat flux on thermal stratification in rocket propellant tanks. Preliminary results have shown that the severity of thermal stratification could be reduced when the total sidewall heat flux was redistributed to increase the fraction into the lower segment of the sidewall.

Parameters that are varied include the test liquids, and the amount and distribution of the sidewall heat flux. A range of Prandtl numbers from 7 to 12,000, and modified Rayleigh numbers from  $10^6$  to  $10^{13}$  are employed with an aspect ratio of 6. The nonuniform wall heating conditions mainly include two series: (1) linearly varying wall heat flux, and (2) a uniform wall heat flux, but with one or several narrow, perfectly insulated strips parallel to the base of the enclosure.

In addition, this research is also an exploration in the phenomenon of separation of a natural convection boundary layer. Factors destabilizing a natural convection boundary layer will be determined using a perturbation method for various combinations of thermal boundary conditions at the wall and the core.

Such an approach will then lead to predictions of how best to insulate rocket propellant tanks to minimize the present detrimental thermal stratification, and hopefully will yield a better understanding of the physical nature of the natural convective flow phenomena.

Further studies were carried out by Professors Reid and Brian to study the structure and physical properties of water frost deposited from a humidified gas stream onto a cold ( $77^\circ\text{K}$ ) test plate. Frost densities and thermal conductivities were measured across frost layers and within the frost layer. One of the more interesting results obtained was that the frost density was uniform throughout the frost, though it increased with time of frosting. An analytical model suitable for machine computation was formulated. It will predict the physical and thermodynamic properties of water frost as a function of time and gas phase temperature, humidity, and Reynolds number.

Professor Reid has a high-pressure, high-temperature liquid calorimeter under construction to measure the heat capacities at constant pressure from reduced temperatures of 0.7 to about 0.95. There are few published values in this high-temperature range, and more reliable data

are needed to develop useful empirical correlations or to test theoretical models.

Temperatures as high as 300°C are envisioned with concomitant pressures of up to 1,000 pounds per square inch absolute. In the calorimeter, temperature differences of 1 millidegree C will be measured. The resulting heat capacity values will be accurate to 0.5 to 1 per cent.

Professor Hales' interest in heat and mass transfer from spherical particles continues. Having completed a numerical study of transport rates from spheres in steady creeping flow, an attempt is now being made to extend this work to intermediate flow rates where experimental results have left considerable doubt as to the actual form of the transport correlation.

Professor Hales has also initiated a study of the effects of centrifugal forces on turbulent fluid flow. It is well known that rotation of the walls of annulus can result in Taylor vortices. When axial flow is present, these vortices degenerate into random turbulent motions. On the other hand, Professor Hales' preliminary work has shown that an opposite effect exists in rotating tubes; that is, rotation about a tube's center line tends to reduce turbulent motions. Study of the two phenomena, of critical importance to rotating equipment such as that used to drill oil wells, continues.

An investigation of the dynamics of spherical particles in flow along a cylinder and in the annular gap between concentric cylinders of which the outside cylinder is in rotation is being made by Professor Gilliland and John T. Day. The ratio of the particle diameter to the diameter of the tube or to the gap width of the couette apparatus ranges between 0.4 and 0.98. Numerical modeling, correlation of data, and experimentation for the tube flow problem are being conducted. The pressure drop in the duct is strongly affected by the particle size, flow rate, and particle spacing. Numerical simulation of a sphere located on the axis of a cylindrical duct is being studied by a variety of models. Two basically different methods of forming the finite difference analogs of the full Navier-Stokes equations were applied, but severe instabilities resulted with both techniques, although the convection terms and the vorticity boundary approximations were formulated several ways. Experimentally, the system in which the spheres are moving with the fluid down the cylindrical duct is being used to procure the following raw data: (1) Flow rate, Reynolds number; (2) pressure drops of the fluid and particles; (3) velocity of the particles; (4) distance of separation. From these data at different ratios of the particle diameter to tube diameter, comparisons are being drawn to the theoretical models.

The data from the concentric cylinder device indicate that the ap-

parent viscosity tends to increase with concentration of particles, shear rate and the ratio of the particle to the gap width. However, at a given shear rate and concentration the apparent viscosity appears to pass through a maximum. The particles seek a preferred configuration of streaming, one behind the other, in string-of-pearls formation.

Recently, two sets of cylinders and bobs were constructed to vary the ratios of gap width to length of the bob and gap width to radius of the bob. These units were used to determine what end effects were prevalent in the primary system, stable configurations of particles, and the relation of the particle velocity to the velocity of the cup.

Experiments have also been conducted using flow visualization techniques to determine qualitatively the flow patterns around particles. Stroboscopic equipment and high-speed photography were employed in an effort to determine the angular velocity of the particles in this flow field.

The work on this project, supervised by Professors Baddour and Gilliland, involves two main areas: (1) flow of molecules adsorbed on surfaces, and (2) the mechanics of flow of suspensions in which the particle diameter approaches that of the pores. In both of these the wall effects are large.

In past studies, helium was used to calibrate the porous solids, using the assumption that the adsorbed flow with this gas was negligible. This assumption has been questioned, and William I. Koch and Robert N. Hindy are investigating this in detail.

Permeability measurements have been taken on six pressed Cab-O-Sil discs covering a temperature and pressure range of 200°K to 500°K and 2 mm Hg to 60 mm Hg. The normalized Knudsen Permeability  $[P(MT)^{1/2}]_T/[P(MT)^{1/2}]_{300}$  is essentially independent of temperature and pressure. The temperature range is being extended to 77°K to 600°K.

Measurements of helium adsorption on Cab-O-Sil have been made, and it has been found that large samples of Cab-O-Sil, 90 grams, are necessary for the detection of any adsorption.

Professor Gilliland, Professor Delbar P. Keily of the Department of Meteorology, and Min-Nan Sze are conducting a study of the basic problems of present anodized aluminum humidity sensors. The major objectives of our investigation will be to obtain data in the areas of response time, reproducibility, and dielectric behavior of this kind of humidity sensor. Both theoretical and experimental approaches are being used in this research. Included is a final design of sensor's configuration for minimum time lag and optimum humidity response with high reproducibility.



## BIOMEDICAL ENGINEERING

Biomedical research in the Department has been done in collaboration with surgeons and physicians from outside institutions. Dr. W. Gerald Austen, Chief of Surgery, Massachusetts General Hospital, and Dr. Edwin W. Salzman, Associate Director of Surgery, Beth Israel Hospital, have participated in the biomaterials development program.

Dr. David C. Shannon, Pulmonary Unit and Pediatrics, Massachusetts General Hospital, Dr. Homayoun Kazemi, Chief, Pulmonary Unit, Massachusetts General Hospital, and Dr. John Hedley-Whyte, Chief, Anesthesiology, Beth Israel Hospital, are collaborating on the lecithin aerosols program.

Dr. David Swan and Dr. Endre Balazs of the Department of Connective Tissue, Institute of Biological and Medical Science, Boston, are collaborating on the program of study on hyaluronic acid.

Dr. Patrick S. L. Wong and Professor Merrill have continued to develop cross-linked hydrogels containing the anticoagulant biopolymer heparin, bonded into the polymeric network. Based primarily on polyvinyl alcohol, the finished gels have permeabilities ranging from exclusion of blood plasma proteins to gross sponge-like porosity, and mechanical properties ranging from glass-clear rubbery gels to opaque, tough, leathery substances. Some of these materials may have applications, especially in ultrafiltration, beyond the originally intended use as materials for contact with blood.

Raymond E. Gerson, in a doctoral thesis supervised by Professor Merrill, has developed a method for synthesizing films of cellulose sulfate. It consists of first cross-linking the cellulose molecules by diisocyanate, then reacting the cross-linked material with sulfur trioxide in dimethyl formamide. The product is highly sulfated, insoluble in water but extensively swollen, and shows promise as an ionic membrane as well as an alternative to heparin-containing materials for biomedical use.

Professor Cottrell completed a doctoral thesis under the direction of Professors Merrill and Smith on the conformation of random coiling macromolecules in dilute solution undergoing shear. Professor Cottrell succeeded in obtaining light-scattering data on solutions contained between coaxial glass cells, of which the inner was rotated. His work attracted international attention because he demonstrated experimentally that the distortion of the macromolecular coil, relative to its unperturbed diameter, was 10- to 100-fold less than predicted by existing theory. He also brought together observations on the shear gradient dependence of intrinsic viscosity with previously unattempted light-scattering studies to reveal new ways of determining the conformation and stiffness of macromolecular coils.

Ross A. Odell is completing a doctoral thesis on the biopolymer hyaluronic acid, using light scattering, intrinsic viscosity, and the gradient dependence of viscosity to assess the shape and hydrodynamic responses of this polymer in dilute solution. The thesis, codirected by Professors Merrill and Cottrell, draws significantly on the work of Cottrell in his doctoral thesis. Through a preparative technique of Dr. Swan, giant hyaluronic acid molecules have been found (perhaps have always existed) having intrinsic viscosity values at zero shear of 130 deciliters/g. Industrial high polymers rarely exceed 15 dl/g, even at mol wt levels of 10 million. Even more interesting is the discovery of well-defined second Newtonian regions, by a combination of the GDM (Couette) viscometer and pressurized capillary viscometers. The work is aimed at attempting to elucidate how hyaluronic acid functions in cartilage, in the fluid lubricant of joints, in connective tissue, and in the vitreous of the eye.

The doctoral thesis of David J. Graves (August, 1967) on the surface active properties of dipalmitoyl lecithin, which was directed by Professors Merrill, Smith, and Gilliland, has been followed by a program of research on the surface viscosity of lecithin under Professor Merrill and an investigation of aerosols generated from lecithin suspensions, which includes a doctoral program codirected by Professors Merrill, Smith, and Hottel.

It has been found that a kind of phase transition occurs in surface layers of dipalmitoyl lecithin, such that its surface viscosity, which is non-Newtonian below 25°C, becomes Newtonian and significantly lower above 25°C, in parallel with observations of Graves that the apparent diffusivity of lecithin in water increased discontinuously at 25°C, and that ultrasonic generation of lecithin aerosols is possible only above 25°C. More remarkable, the aerosols that are ultrasonically generated from lecithin suspensions have particle diameters (0.5 micron) smaller by an order of magnitude than those generated from water under identical operating conditions. Presumably the surface tension operating on the lecithin aerosol particles is nearly zero, since it can be easily shown that under the surface tension of pure water, the particles would disappear within milliseconds from the instant of generation, owing to the enhancement of vapor pressure (Poynting relation) attributable to their internal pressures (Laplace law). The hysteresis in the surface tension-surface area relation of lecithin suspensions, and the possibility of near-zero surface tension was demonstrated in the thesis of Graves by cinephotography of sessile bubbles in lecithin suspensions following step changes in their volumes.

The medical applicability of the lecithin aerosol was demonstrated at Shriners Burns Institute of Massachusetts General Hospital on Decem-

ber 10, 1968, by its use on a child dying from pulmonary failure after inhaling flame from a space heater explosion. One hour after the administration of the lecithin aerosol, the progressive pulmonary failure was reversed, and the child recovered.

Professors Smith, Merrill, and Evans have continued their investigations of engineering problems associated with artificial organs. Professor Colton, working in cooperation with them, has constructed an analytical model of the artificial kidney and has developed novel experimental techniques for the independent determination of the necessary input parameters: membrane permeability to the solute of interest, and solute diffusivity in whole blood. Performance predictions, based upon the experimentally determined values of the input parameters, compare very favorably with the performance of a small artificial kidney, which was also constructed. Peculiarly biological phenomena such as protein denaturation and red blood cell tumbling appear to play little or no role insofar as mass transport is concerned.

In a related study, Arun N. Dravid has been studying mass transfer in helical coils. This study is being directed by Professors Smith, Merrill, and Brian and is motivated by the possibility of augmenting mass transfer rates in artificial organs. Work to date has already revealed bizarre effects such as concentration overshoots, and it is believed that a quantitative evaluation of the concept will soon be possible.

A study has just been completed under the supervision of Professor Hoffman on the swelling behavior and viscoelastic properties of elastin in various polar organic or aqueous salt solutions. Elastin is a major component of the blood vessels, such as the aorta, and ligaments in the body, and it is hoped that these studies will aid in a better understanding of aging and arteriosclerosis. Elastin behaves as a cross-linked nonpolar rubber, and estimates of the average molecular weight between cross-links ( $M_c$ ) are obtained from the viscoelastic data. It has been found that purified elastin samples exhibit increased  $M_c$  values in a polar organic solvent as formamide, or in mixtures of formamide and water. However, when these solvent systems are exchanged with water and the  $M_c$  remeasured in water, there is a marked irreversibility noted for the  $M_c$  values of those samples previously in 25 per cent and 50 per cent formamide/water solutions, while the samples previously in 75 per cent and 100 per cent formamide/water solutions display almost complete return of  $M_c$  to the lower values noted in water. Aqueous sodium iodide solutions also cause a sharp rise in  $M_c$  at as low a concentration as 0.1 per cent NaI (1,000 parts per million), and this effect is irreversible, that is,  $M_c$  values remain high even after leaching out the NaI. These results have been interpreted in terms of the molecular structure and

arrangement of the polypeptide chains between crosslinks within the elastin matrix. Dr. Carl Franzblau and Marott F. Sinex of the Boston University Medical Research Center, well known for their work on elastin, have been invaluable in their assistance to this project.

#### WATER DESALINATION

Professors Sherwood, Brian, Sarofim, and Smith are studying aspects of the freezing process for desalination under a grant from the Office of Saline Water (osw). Freezing processes for the production of fresh water from sea water have the important advantage that very little metal heat transfer equipment is needed. Saline solutions are frozen to produce pure-water ice by direct contact with refrigerant, and the washed ice is melted by direct contact with a condensing vapor. The heat exchange between saline feed and two product streams introduces the only important requirement for metal heat exchange surface.

The ice is produced as a slurry or suspension of small ice crystals in concentrated brine. Present practice is to remove the brine and wash the ice as a consolidated "plug" in a vertical wash column. A study of wash column operation has recently been completed and a detailed report of the results, which were given here a year ago, will soon be published by osw. Efficient washing by this technique depends on the quality of the slurry produced in the freezer; most important are the size distribution of the ice crystals and the resulting permeability of the ice plug. Tests on a laboratory-scale continuous crystallizer during the past year have provided data on ice-crystal size distribution and on permeabilities of beds formed by the ice-slurry product from the crystallizer. The ice crystals were in the form of disks with a thickness-to-diameter ratio of about 0.34, and had a size distribution that showed a peak at 0.6 to 0.8 mm, with few crystals smaller than 0.4 mm or larger than 2 mm. Two-fold variations in residence time, ice-slurry density, and temperature difference between the brine solution and the vaporizing refrigerant had little effect on the size distribution. The permeabilities of the ice beds formed from the product slurries were found to increase sharply with bed porosity and to be very dependent on the method of formation of the ice bed, a factor which could be important in determining wash column performance.

Another significant finding in the study of the continuous crystallizer was that the principal thermodynamic loss in freezing is due to the temperature difference required to transfer heat from brine to refrigerant and not from the ice crystals to the brine. This suggests that better dispersion of the liquid refrigerant would reduce this source of thermodynamic

loss, while at the same time increasing the rate of ice production per unit of freezer volume.

Another source of thermodynamic loss is the temperature differential required to transfer heat from the condensing vapor on ice in the melter-condenser employed in the freezing process. The vapor, which may be that of either water or an immiscible organic refrigerant, flows directly into the porous ice mass and condenses with attendant melting of the ice. An analysis has been performed which shows that, in the absence of noncondensibles, the rate is severely limited by frictional resistance to vapor flow within the bed. This prediction has been tentatively confirmed in some rather crude preliminary experiments. The construction of a far more sophisticated apparatus which permits the measurement of quantities such as the noncondensable concentration level has now been completed. The anticipated precision of these measurement techniques has been experimentally confirmed and system data should be forthcoming shortly.

Professors Hoffman and Modell and Samuel M. Fleming are investigating the preparation and properties of new membranes prepared by terpolymerizing or tetrapolymerizing various acrylic monomers, in order to develop new and useful reverse osmosis desalination membranes. The membranes are first characterized by their salt and water contents as a function of salt concentration in solution. Following this, their reverse osmosis performance is studied. The results have been interpreted in terms of a model that depicts two water-transport mechanisms: primary H-bonded water free of salt, and secondary water associated with salt ions. From this analysis, predictions have been made as to how composition should be changed to obtain improved flux and permselectivity to water, and these predictions have recently been verified experimentally. In general, the requirements for optimum flux-rejection properties are: a high concentration of hydrophilic sites, randomly distributed in a lightly cross-linked matrix above its glass transition temperature under use conditions. Some of the membranes developed are better in performance (flux and salt rejection) than dense, homogeneous cellulose acetate; work is in progress to polymerize the best monomer compositions in thin layers of porous supports. Sorption isotherms are also being measured for a series of membrane compositions in which the hydrophilic monomer content is progressively increased. Zimm-Lundberg cluster integrals can be calculated from these isotherms and the results are being used to correlate reverse osmosis performance with the distribution of water within the membrane.

A program for the development of materials for reverse osmosis membranes is being carried out by Stuart M. Nemser under the supervision

of Professor Gilliland and Mr. Fleming. Membranes are being made from solutions of highly esterified cellulose esters mixed with flux-promoting hydrophilic polymers. Studies have been made with cellulose triacetate (CTA) mixed with either polyethylene glycol (PEG) or polyvinyl-pyrrolidone (PVP). Using 4 weight per cent NaCl, and at a pressure of 1,500 pounds per square inch (psi), the pure homogeneous CTA rejects 99.3 per cent of the salt and has a water flow of only 0.02 gal-mil/square foot/day. Incorporation of either 9 per cent PVP or 9 per cent PEG into CTA membranes increases the water flux by a factor of 5 to 6 with no decrease in salt rejection. Addition of 17 per cent PVP to CTA membranes does not increase the flow over that of 9 per cent addition, but the salt rejection decreases to 80 per cent. On the other hand, addition of 17 per cent PEG increases the flow rate by a factor of 20 over pure CTA membranes, while the rejection drops to only 87 per cent.

The investigation is being continued with PEG and PVP concentrations over a greater range and with other hydrophilic flux-promoting polymers.

A project directed toward fundamental understanding of the structural factors limiting the rates of selective molecular transport through semi-permeable membranes was initiated by Mr. Fleming. Attention has been focused on experimental and theoretical study of the permeation of water and an electrolytic solute (NaCl) through cellulose nitrate membranes. This approach was taken because of the current interest in membrane transport processes, such as reverse osmosis, related to desalination of water.

Cellulose nitrate has excellent salt rejection properties and good chemical stability, but rates of flow of desalted water through the membranes are very low. The question arises as to how the rate of permeation of water through the cellulose nitrate can be promoted, and if the rate can be increased markedly, what is the effect on the rate of permeation of solutes such as salt?

The approach used thus far has been to cast cellulose nitrate membranes from solution of controlled composition. The organic solvent for the cellulose nitrate is a mixture of a good solvent (acetone or "Ethyl Cellosolve") and a moderately poor solvent (dioxane and/or water). This general technique of preparing membranes is not new, but apparently has not been used successfully in preparation of cellulose nitrate membranes for water desalination.

The initial test results are encouraging; when tested with 1.5N NaCl brine (which is slightly more concentrated in NaCl than sea water) at 1500 psi, 25°C, expanded cellulose nitrate membranes have given 99.5 per cent rejection of NaCl at a water flux of 1.5 gallons per day per square foot of membrane surface. This rejection is adequate to give

drinkable water in a single pass through the membrane. The water flux rate is substantially lower than that observed for cellulose acetate under comparable test conditions, and is at least an order of magnitude lower than that required for practical interest. However, it is significant that the product flux through the membrane is two orders of magnitude higher than that through unexpanded cellulose nitrate films, and the intrinsically high rejection of cellulose nitrate films has been retained.

Several obvious questions arise: How much further can the flux be increased before the membrane loses selectivity for water over salt? How is the enhancement in rate of permeation related to membrane structure and to changes in the equilibrium sorption characteristics of the material? What physical models are applicable to description of transport and equilibrium behavior? How general is the technique for promoting transport rates? The study is aimed at answering such questions.

#### ELECTROCHEMISTRY

Professors Meissner and Deibert are investigating a potentially novel process for recovering electrorefined metals and elemental sulfur from metal sulfide ores in a one-step electrochemical system. Current direct electrorefining technology works only for nickel sulfide treatment, requires the casting of massive nickel sulfide anodes, and is semi-batch, with attendant high labor costs. The new process under study would operate continuously on the finely divided metal sulfides recovered in existing froth flotation equipment. The process shows promise for both nickel and copper sulfide ores. Preliminary experiments indicate that a redox system couples the metal sulfide oxidation to the electro-oxidation reaction occurring on the anode.

A study has been made by Robert H. Havlin under the supervision of Professors Evans and Gilliland of the theoretical flux equations which would describe the flow of ions through a porous membrane due to diffusional, electrical and hydrodynamical driving forces.

Experiments were conducted in a two-compartment cell with Millipore-type GS filter as a membrane using sodium or potassium chloride as electrolyte. Each compartment contained a single-blade stirrer and a silver-silver chloride electrode. Tests were made (1) of diffusion due to a concentration gradient alone, (2) with simultaneous diffusion and electrical transfer, (3) with simultaneous diffusion and hydraulic flow, and (4) with all transfer processes. The diffusion experiments were used to evaluate a tortuosity factor of 1.23 and the hydraulic flow tests were used to determine a diffusion blockage coefficient which should be a function of pore size distribution and structure. Models considered were: (1) a uniform pore model that required the pores to be of the same diameter,

and to maintain this diameter across the membrane, but allowed for some structural variation through a tortuosity factor; (2) a series model consisting of alternating layers, each of which could be considered as a miniature uniform pore model membrane; (3) a gamma distribution model that allowed the diameter of the pores to vary according to a gamma distribution, while retaining their individual diameters across the membrane; and (4) a bimodal distribution model in which the pores were of two distinct diameters. The data and the models were used to estimate the mean pore diameter and the pore size distribution. Mercury intrusion measurements were also made to gain additional insight into the pore size distribution. Mean pore diameters from 0.38 to 0.47 microns were obtained.

#### COMPUTER STUDIES OF PROCESS DESIGN AND ESTIMATION OF PHYSICAL PROPERTIES OF CHEMICAL COMPOUNDS

Professor Evans is investigating the problem of optimal design and control of batch processes for bulk polymerization. The work is focusing upon systems involving the addition polymerization by a free radical mechanism in the bulk of monomer without diluent. As a specific example, the bulk polymerization of styrene is being used to demonstrate and test the general conclusions from this work.

The characteristic feature that makes polymerization systems distinctly different from other common chemical reaction systems is the large number of chemical species and reactions that are involved. If one considers polymer molecules and free radicals of each different chain length as a separate species, then there may be many thousands of separate species in a typical polymerization system. One of the primary objectives of this work is to determine the appropriate degree of simplification in the mathematical description of polymerization processes for use in studies of design and control.

The general approach planned for the study is to consider two idealized reactor configurations: the well-stirred batch reactor, and the unstirred batch reactor in which polymerizing material is confined within an enclosure and heat is removed at the boundaries. The first system can be modeled as a lumped-parameter system, while the second must be treated as a distributed-parameter system.

The mathematical models developed for each configuration will be used with suitable numerical techniques to simulate the process and to compute solutions to the problems of optimal design and control. The results of the computations will be compared with experimental data either taken from the literature or obtained as part of the study.

Professor Evans, with the cooperation of Professor Leonard A. Gould



of the Department of Electrical Engineering, is investigating techniques for use in the development of comprehensive programs for computer-aided chemical process design. A major task of such programs is simulating the steady-state performance of large, integrated chemical processes, consisting of many interconnected processing units with recycle streams.

The problems involved in developing effective programs for computer-aided design fall into three general areas: designing an effective data structure to represent the simulation problem within the computer, developing reliable and efficient algorithms for solving the systems of simultaneous nonlinear equations that result, and devising convenient techniques for communication with the user of the system.

A prototype system for designing networks of heat exchangers is being developed using computer programming techniques developed by the A.E.D. (Automated Engineering Design) Project at M.I.T. The prototype system operates on a time-shared computer and has the option of man-computer interaction by means of a graphical input-output terminal.

Professors Evans and Smith are conducting a study of natural convection in a porous material. In the initial phase of the work, a theoretical analysis was made of transient natural convection in a porous material. The partial differential equations based upon conservation of mass, momentum, and energy were derived for the general case in which the fluid and solid phases at any position are not necessarily at the same temperature. Darcy's law was used to describe the fluid flow through the porous structure. Four dimensionless groups are required to characterize the general problem for a nonhomogeneous medium in which the fluid and solid temperatures are distinguished.

Solutions were obtained for two particular geometries: (1) the one-dimensional problem of a saturated solid confined by two isothermal, parallel vertical plates maintained at different temperatures, and (2) the two-dimensional problem of a saturated solid near an isothermal, semi-infinite vertical plate that has been subjected to a step-change in temperature. An analytical solution was obtained for the first problem. A computational technique based upon numerical solution of a set of finite-difference approximations was developed and used for the second problem.

The next step in the study will be to complete a theoretical analysis of steady-state natural convection in a rectangular cavity filled with porous material. An experimental program will be carried out simultaneously to test the conclusions of the theoretical work.

EDWIN R. GILLILAND  
RAYMOND F. BADDOUR

**DEPARTMENT OF CIVIL ENGINEERING**

The scope of the activities of the Department of Civil Engineering increased significantly during the year. New programs, projects, and subjects were introduced in such areas as transportation, housing, water resources, pollution, and construction technology. The Department played a leading role in developing an Institute-wide response to the pressing problems of society through a variety of interdepartmental and interdisciplinary activities.

The new interdepartmental Urban Systems Laboratory (U.S.L.) was a focal point for many of the new activities of the department during the year. While faculty and students from many departments participated in the work of the laboratory, the Department of Civil Engineering played the leading role in getting the new Institute-wide activity underway. Professor Charles L. Miller served as Director of U.S.L., and Frank S. Jones, Senior Lecturer in the Department, served as Assistant Director. At the end of the year, Mr. Jones was appointed to the faculty of the Department as Professor of Urban Affairs. During the year, over half of the faculty and students of the Department participated in the activities of U.S.L.

As an example of new activities initiated through U.S.L., Professors Ronald C. Hirschfeld and Fred Moavenzadeh served as co-directors of a new community research project, conducted jointly with the Boston Redevelopment Authority. The project, involving an interdisciplinary staff of 30, is concerned with the planning and design of new communities based on advanced technology, with particular reference to new community possibilities in Boston. Both undergraduate and graduate students are participating in the project. They represent such disciplines as political science, economics, architecture, city planning, sociology, and civil engineering. Students from Harvard University, Boston College, and other local colleges are working on the project also.

The largest project under way in U.S.L., the CARS Project (computer aided routing system), is under the leadership of Professor Daniel Roos, Director of the Civil Engineering Systems Lab. The project, sponsored by the Urban Mass Transportation Administration of the U.S. Department of Transportation, is concerned with the development of a new dynamic computer-controlled public transportation system. A major field experiment and demonstration is being planned. The staff presently numbers over seventy researchers at the Institute, drawn from the Departments of Civil Engineering, City and Regional Planning, Electrical Engineering, Political Science, Economics, and Management, as well as the Electronics Systems Laboratory, the Civil Engineering Systems Laboratory, and the Instrumentation Laboratory.

**UNDERGRADUATE TEACHING**

The undergraduate teaching program, supervised by Professor Robert V. Whitman as Undergraduate Academic Officer of the Department, was advanced during the year through many changes in the programs and subjects of instruction. The undesignated degree program now offered to undergraduates continued to grow and to attract high caliber students. While urban planning and transportation are the most popular special programs, individual students are using the very flexible arrangement to pursue such interests as ocean engineering and secondary education. The undesignated degree program showed considerable potential for the Department to play an expanded role in undergraduate education at the Institute.

The senior year projects course, lead by Professor Whitman, was again highly successful. The case study for the year was the student design of a new stadium for Boston, a project of considerable local interest and controversy. The student solutions attracted the attention of local public officials and business leaders. At the suggestion of the students, consideration is being given to conducting the course over both terms in the senior year as well as, perhaps, for the second and third years. A series of project courses running parallel with the discipline-oriented studies is advocated by many and is being considered.

Professors Richard L. deNeufville and Joseph H. Stafford presented an exciting freshman seminar on Urban Systems Analysis which also focused on Boston. Many first-year students are highly motivated to work on problems of the city, and such seminars are very attractive to them. A number of the freshmen who took the seminar were subsequently hired as student assistants on various urban research projects in the Urban Systems Laboratory. We anticipate an expansion of such teaching and research efforts with first and second year students.

Subject 1.00, Information Systems, continued to attract a growing number of undergraduates with over 400 students registering for the subject. Thirteen faculty members and 23 staff members participated in the teaching of the subject in a department-wide effort to assist in the undergraduate education. The hands-on experience approach to the teaching of computer systems, coupled with close student-instructor interaction in small groups, while very expensive in staff and computer time, continues to be very successful and attractive to the students. A little known fact is that each year the Department teaches well over half of the undergraduate student body at the Institute at least one subject. This is accomplished through registration of students in Information Systems, the Civil Engineering Laboratory elective and non-civil engineering majors in regular subjects and freshman seminars.

A major event of the year was the publication of *Soil Mechanics* by Professors Thomas W. Lambe and Whitman. The book has been progressing for a number of years as a part of the undergraduate curriculum development project and is the product of considerable work. In addition to serving as an introductory text, the book contains significant material for advanced students and practicing engineers. Initial reaction to the book has been very encouraging. This is the second book to come out of the undergraduate curriculum project, the first being *Fluid Dynamics* by Professors Donald R. F. Harleman and James Dailey.

#### GRADUATE TEACHING

Over half of the graduate students in the Department are now registered as doctoral candidates. With approximately 100 doctoral students to supervise, the faculty is heavily burdened with doctoral program activities, in addition to graduate teaching. Since most of our S.M. candidates hope to continue with the doctoral program, we have reached a point where the doctoral program is the primary graduate study program of the Department. This shift has numerous implications for the operations of civil engineering, and we are adjusting accordingly.

Professor Peter S. Eagleson is directing a major new development in our academic program in water resources. He has completed the manuscript for a new text, *Dynamic Hydrology*, which is being used in his new hydrologic systems courses. Under the auspices of Professors John C. Schaake Jr. and Frank E. Perkins, the water resources systems course has been substantially changed. Special emphasis is being given to urban water problems and to the generation of computer models in water resource systems. New subjects in water quality management and in public investment are being developed and will be taught by two new members of the faculty, Professor David H. Marks, Ph.D. in operations research from Johns Hopkins University, and Professor David C. Major, Ph.D. in economics from Harvard University. These additions to our faculty significantly strengthen and broaden our program in water resources. As examples of interaction between teaching and research in water resources, the New York City and Boston research projects conducted through the Urban Systems Laboratory were used in class work on network models and pollution models during the year. Professor Lynn W. Gelhar's graduate course in water quality control also interacted with state and local government in studying water pollution problems.

New subjects in structures introduced during the year included Optimization of Structures by Professor Kenneth F. Reinschmidt, Linear Methods of Engineering Analysis by Professor Reinschmidt, Planning of Structural Systems by Professor William A. Litle, Behavior of Metal

Structures by Professor Litle, Structural Information Systems by Professor Robert D. Logcher, and Building Design Systems by Professor Alan M. Hershdorfer. Professors Myle J. Holley Jr., Robert J. Hansen, and John M. Biggs collaborated on the presentation of a new subject on the practice of structural engineering which, in addition to technical considerations, considers difficult professional problems which can confront the practicing engineer. Professors Jerome J. Connor Jr. and Jose M. Roesset have been reorganizing the graduate courses in structural mechanics and structural analysis, developing a new core. Professor Connor conducted numerous experiments and innovations in teaching with extensive student participation. He also continued his excellent progress in computer based technology and finite element methods as applied to teaching. Professor Roesset made extensive use of STRUDL (Structural Design Language) in his teaching and developed two student manuals which are major accomplishments.

The academic program in transportation systems is an area of extensive curriculum development work. Under the leadership of Professor Marvin L. Manheim, the program is undergoing major change, with the inter-relation of technology and society as the theme. The basic physical and economic characteristics of the various transport modes, the various systems analysis techniques, such as mathematical programming and computer simulation, were introduced. In parallel, consideration was given to the different impacts that alternative transportation systems have on various groups in society, including various income classes and operators, and on the environment through air and noise pollution and disruption of communities. This transportation technology is being analyzed as an instrument of social policy.

Professors deNeufville and Stafford continued the development of their engineering systems analysis courses. A new text for use in such courses is in an advanced stage of development as an outgrowth of the course notes. A series of case problems, complete with computer programs and solution sets, is being documented for use in conjunction with the courses. The New York City water supply problem was used in the course this year. Professor Hershdorfer introduced a new course in urban systems analysis. The planning of medical services for low-income groups was the application area treated in the first offering.

#### RESEARCH

The research operations of the Department continued to expand during the year in the face of a tightening of research funding. The research support situation tended to level the recent growth rate and caused major shifts in sources of support. As a result, many new projects were started,

a great number in new areas. Heavy participation in the Urban Systems Laboratory also had great impact on the research program. Practically all of the research in the Department, which now totals over \$2 million per year in volume, is for civilian agencies of government and private organizations.

The various joint research projects of the M.I.T. Inter-American Program in Civil Engineering continued to be our most fruitful and rewarding research effort. Earthquake research has become a major theme of collaboration in IAP, not only between universities but within the Department. Professors Whitman, Carl A. Cornell, and Roesset have led the effort, which has involved extensive participation of staff at the University of Chile and the University of Mexico. Professor Cornell published his new method of seismic risk analysis which is now being applied by engineers and seismologists in the United States and abroad. Professor Roesset developed powerful computer programs to implement the earthquake research. Professor Whitman extended his research into the safety of the economical setting and design of nuclear power plants in areas of seismic activity.

Another area of considerable interest to the Department was the NSF (National Science Foundation) sponsored project "Computer-Aided Teaching." More than ten faculty members were involved in this project which was concerned with the effective and efficient use of the computer in classroom and laboratory instruction. Eleven manuals were published as a result of this research using, in many instances, the capabilities of the ICES (Integrated Civil Engineering System) system as the basic component. The manuals were distributed to 150 civil engineering departments throughout the country, and the initial reaction to the manuals has been most gratifying.

We have tested the results in our own academic courses and found that students respond favorably to using the computer as an integral part of any analysis or design problem. It also gives them an opportunity to attempt realistically to solve relevant problems of complex nature without idealizing the problem.

The ICEP (Integrated Civil Engineering Project) research work being done under the general direction of Professor Lambe in the area of predicting, measuring, and analyzing large scale construction projects continued to expand. Some of the more important current ICEP projects include a highway embankment on a deep deposit of soft clay in Revere, Massachusetts; flood control levees in New Orleans, Louisiana; two large braced excavations for subway extensions in the greater Boston area; and a breakwater harbor structure at Brega, Libya.

These projects form the focus of activities and enable us to advance

the technology of civil engineering construction. Students are attracted to and motivated by these factual construction projects, both as a source of economic support and as subject material. The younger faculty have a unique opportunity to gain practical experience.

The CARS project and the New Community research project previously described added to the breadth of the Department's research activities during the past year, with 85 active research projects being worked on in the Department. It has opened up new opportunities for faculty and students to pursue their professional interests. Having been able to obtain research funding from new sources, we are hopeful of maintaining our research momentum and strengthening our contribution to the profession.

#### EQUIPMENT AND FACILITIES

Adequate space and equipment continued to be the most serious constraint on the Department. The Building 1 operations were handicapped by the stress of overloaded facilities, compounded by the pressure for space for new and expanding programs in all units of the Department. In one area, space relief is now in sight. Construction work started during the year on the addition of two floors to Building 48. By the fall of 1969, space for an expanded laboratory for water resources will be achieved.

Professor Gelhar has been primarily responsible for the planning of the new facilities represented by the expanded Building 48. He has performed an outstanding service to the Department and to his colleagues in this very complex undertaking, involving long hours and many difficulties. Professor Arthur T. Ippen has also been deeply involved in the project, which represents a decade of effort on his part to achieve a first-rate laboratory facility for teaching and research in water resources.

Progress was also made in equipping the Materials Research Laboratory with the significant addition of a scanning electron microscope. This valuable and versatile instrument will allow new research of fundamental study of civil engineering materials to take place. Professors Frederick J. McGarry and Russel C. Jones are planning an extensive new research program based on innovative use of the scanning electron microscope.

In the computer area, there were major changes in the equipment. In the summer of 1968, the IBM 360/40 in the Civil Engineering Systems Lab (CESL), was released. It had been the first such third-generation computer in a university in the world at the time of its installation in 1965. The machine played a key role in the development of the ICES system and was highly successful. Its productiveness in teaching and research will be hard to match or achieve again. With the release of the 360/40, attention turned to the IBM 360/67 installed by the Urban Systems Laboratory in the summer of 1968. Staff from the Department

and U.S.L. were responsible for bringing the large time-sharing machine in and operating, with Miss Mary E. Schumacker, Lecturer in Civil Engineering, serving as Project Manager. During the year, computer work was shifted to the large machines achieving remote terminal mode at CESL.

The IBM 1130 in CESL was upgraded to 16 K core, three disk drives, and high speed input/output. Software was developed to operate the 1130 as a remote I/O station to the 360/65 and 360/67. Two units of A.R.D.S. (Advanced Remote Display Station) graphics terminals were obtained which can operate on line with the time-shared computer and on the 1130.

#### PROFESSIONAL ACTIVITIES

The faculty of the Department played important roles during the year in a wide range of professional organizations and activities. Professor Mannheim served as Academic Vice President of the Transportation Research Forum and Regional Editor of *Transportation Research*. Professor Perkins served as Chairman of the newly formed Computer Section of the Boston Society of Civil Engineers. Professor R. C. Jones served as Vice President of the Massachusetts Section of the American Society of Civil Engineers. Professor Ippen served as Chairman of the International Union of Engineering Organizations. Professor Whitman served as Chairman of the Research Committee of the Soil Mechanics Division of A.S.C.E. (American Society of Civil Engineers).

Professor Leslie G. Bromwell was elected to membership in the A.S.C.E. Committee on Soil Properties and is on the Highway Research Board Committee of Physical-Chemical Properties of Soils. Professor John T. Christian served on the A.S.C.E. Committee on Automatic Computation. Professor Hirschfeld served as Secretary of the U.S. National Committee of the International Society of Soil Mechanics and as Chairman of the A.S.C.E. and Geological Society of America Joint Committee on Engineering Geology. Professor Ladd was chairman of the committee which organized a new geotechnical section of the Boston Society of Civil Engineers.

Professor Raph H. Cross III served as Chairman of the Task Committee on Selected References for the A.S.C.E. Council on Ocean Engineering. Professor deNeufville was Session Chairman for the Engineers' Day Meeting on Urban Systems for the Engineering Societies of New England. Professor Schaake served as a member of the control group of the A.S.C.E. Urban Hydrology Research Council. Professor Connor was a member of the subcommittee on Mathematical Methods of the A.S.C.E. Engineering Mechanics Division. Professor Joseph M. Sussman was



Chairman of the Spring Joint Computer Conference Session on the application of the Computer in the Urban Context.

Professor Eagleson served as Chairman of the Committee on Education and Research in Hydrology of the Universities Council on Water Resources, Chairman, A.S.C.E. Task Committee on Small Watershed Research, and as a member of the Committee on Water Resources Systems of the American Geophysical Union. Professor Logcher was a member of the Committee on Electronic Computation of the A.S.C.E. Structures Division. Professor Hershdorfer served as Chairman of the Association for Computing Machinery's Special Interest Group in Urban Data Systems, Planning, Architecture, and Civil Engineering, which now has over 800 members.

Professor Little served on A.S.C.E. and American Concrete Institute (A.C.I.) committees on structural models. Professor Holley served on ACI committees on structural safety and nuclear reactors. Professor Cornell served on an A.S.C.E. Committee on Probabilistic Methods. Professor Biggs was on the Executive Committee of the A.S.C.E. structures Division.

#### OTHER ACTIVITIES

The Department was host to many special conferences during the year. During the summer, the Department hosted the National Hydraulics Conference and the Soils Specialty Conference of the American Society of Civil Engineers. Special summer programs were conducted in Finite Element Methods and Engineering Systems Analysis. During the spring, a conference on Seismic Design for Nuclear Power Plants was presented. These conferences brought approximately 1,000 engineers to the campus, and while they required an enormous amount of work on the part of the faculty and staff, they represented significant contributions to the profession.

The faculty of the Department was very active in public service activities during the year. Professor Miller headed President-Elect Nixon's Task Force on Transportation. Professor deNeufville headed Governor-Elect Sargent's Task Force on Transportation. Many members of the faculty and staff made significant contributions to these two important efforts. Professor Hansen was awarded a Distinguished Service Citation for his service to the Department of Defense.

Important awards to the faculty during the year included: an honorary Doctor of Science award to Professor Ippen by the University of Manchester, England, on the occasion of the Osborne Reynolds Centenary; and the Thomas A. Middlebrook Award of the American Society of Civil Engineers to Professor David J. D'Appolonia.

CHARLES L. MILLER

**DEPARTMENT OF ELECTRICAL ENGINEERING****ACADEMIC ACTIVITIES**

During the year, the enrollment in the Department was as shown in Table I. Of the 703 undergraduates indicated in this table, 87 were enrolled in Course VI-A, the Department's cooperative course. The degrees awarded to these students are indicated in Table II. The composition of the faculty and staff engaged in the Department's teaching and research activities during the year is shown in Table III.

**Table I 1968-69 Enrollment in the Department**

	VI-1	VI-2	Total
Sophomores	171	36	207
Juniors	185	59	244
Seniors	177	75	252
Graduate students	437		437
<b>Total Students</b>	<b>970</b>	<b>170</b>	<b>1,140</b>

**Table II Degrees Awarded during the Year**

Bachelor of Science	201
Master of Science	168
Electrical Engineer	59
Doctor of Philosophy and Doctor of Science	44
<b>Total degrees awarded</b>	<b>472</b>

**Table III Composition of the Faculty and Staff of the Department during the Year**

Professors	52
Associate Professors	27
Assistant Professors	45
Professors Emeriti and Senior Lecturers	2
Lecturers	21
Research Associates	6
Instructors (graduate students)	17
Teaching Assistants	101
Research Assistants	120

**DEPARTMENTAL ORGANIZATION**

The complexity of the Department's operations continues to increase. There are several major contributing factors, all more or less independent from each of the others.

The widespread activities that engage the professional interests of electrical engineers are only partly reflected in the Department's undergraduate curriculum. Nevertheless, there are now six formal programs that lead to the Bachelor's degree within the Department of Electrical Engineering. These are:

**Course VI**

Program 1 : Electrical Engineering

Program 2 : Electrical Science and Engineering

Program 3 : Computer Science and Engineering

and the cooperative versions of these programs :

**Course VI-A**

Program 1 : Electrical Engineering

Program 2 : Electrical Science and Engineering

Program 3 : Computer Science and Engineering

In the near future, it is likely that the Department will add a program in biomedical engineering with its cooperative version. Traditionally, the Department has permitted rather wide deviations from its formal curricula if alternative, well-thought-out educational programs are requested by individual students. Also, a growing number of students following one of the standard curricula are tending to take the required subjects at nonstandard times. This combination of activities has placed a growing load on the Department's advisory system, and also has made the processes associated with generating teaching assignments more complex. For example, most subjects offered by the Department must be taught during both terms; some subjects will have essentially the same enrollment each term, others will have vastly differing enrollments from term to term.

During the past year, the pattern of research grants and contracts has continued to grow more complex. The scrambling to find new grants and contracts to replace those that either expired or were not renewed requires the constant shifting of faculty and staff salary changes among the appropriate account numbers.

As a result of these and other pressures, it has been necessary to expand the administrative structure of the Department and to introduce a number of new responsible positions. Following the death of Professor Carlton E. Tucker in 1966, Professor James D. Bruce assumed the responsibility of overseeing the Department's teaching assignments. He has now been named Executive Officer of the Department and has responsibilities in the areas of teaching and research assignments, departmental budgets, personnel, and class schedules. Assisting him are Harmon E. Brammer, Administrative Officer, and Max M. Byer, Administrative

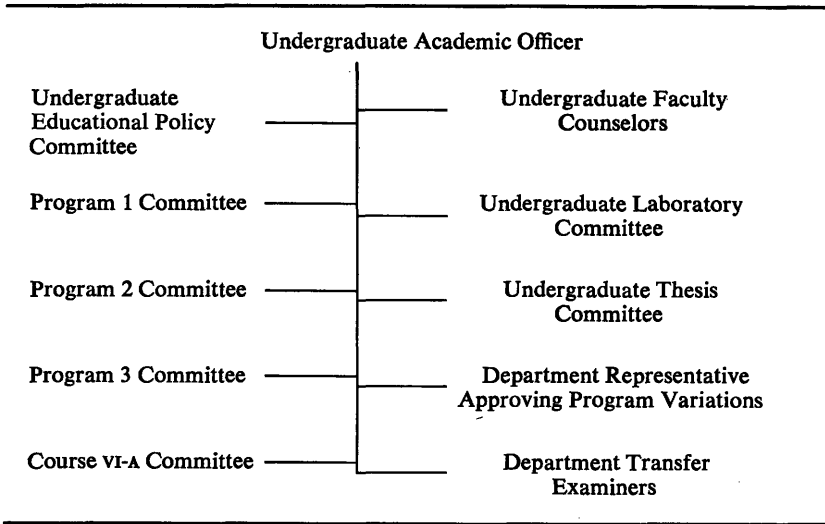
Assistant. Mr. Brammer will have responsibilities in the areas of the operating budget, research assistant appointments, secretarial and student personnel, computer time allocations, office assignments, and parking. Mr. Byer is the principal accounting officer of the Department and has the responsibility of administering the Department's many accounts, in particular as they relate to purchasing and payroll.

During the past three years, Professor Bruce and a group of his students have been developing a computer-based data management system for use in the Department's administrative activities. Specifically, they have developed a programming language, SPLP (Special Purpose List Processor), which permits easy manipulation of text-like data as well as the usual arithmetic operations. With the SPLP language as a tool and the Department's teaching and research assignments as a data base stored on line in a time-shared computer system, programs have been written to greatly simplify tasks such as generating teaching assignments, and overseeing the budget. Success in these areas has led the Department to establish a similar data base containing the records of its graduate students. Programs are now being written to maintain these data bases as well as to extract selected data in the form of reports. Since March, 1969, this work has been partially supported by funds from the Office of Naval Research through a contract with Project MAC.

In order to handle undergraduate academic affairs more expeditiously, the Department has established an Office of Undergraduate Education under the Chairmanship of Professor Wilbur B. Davenport Jr. Professor Davenport succeeded Professor Hermann A. Haus as the Department's Undergraduate Academic Officer at the beginning of the year. The structure of this office is shown in Table IV. For the coming year the chairmen of the various committees listed there will be: Undergraduate Academic Officer and Chairman, Undergraduate Educational Policy Committee, Professor Davenport; Chairman, Program 1 Committee, Professor James R. Melcher; Chairman, Program 2 Committee, Professor Richard B. Adler; Chairman, Program 3 Committee, Professor Frederick C. Hennie; Chairman, Course VI-A Committee and Coordinator of Course VI-A, John A. Tucker; Chairman, Undergraduate Faculty Counselors, Professor Robert S. Kennedy; Chairman, Undergraduate Laboratory Committee, Professor William F. Schreiber; and Chairman, Undergraduate Thesis Committee, Professor Robert L. Kyhl.

Mr. Tucker, who was, until May 30, 1969, Administrative Officer of the Department, has replaced Professor J. Francis Reintjes as Coordinator of Course VI-A, the Department's cooperative program. In addition, Mr. Tucker will be Executive Officer for Student Affairs. As Executive Officer for Student Affairs, he will work with student organizations such as Eta

**Table IV Structure of the Office of Undergraduate Education, Department of Electrical Engineering**



Kappa Nu and Student-Faculty Committee; he will serve as the Department Placement Officer, and be general ombudsman for the Department's undergraduate students.

In the Department's Graduate Student Office, Professor Campbell L. Searle has succeeded Professor Truman S. Gray as Chairman of the Department's Committee on Graduate Students. Professor Gray performed yeoman service with this Committee for at least a decade and requested to be relieved in order to have a sabbatical leave.

**UNDERGRADUATE PROGRAMS**

During the past year work continued on the development and modification of the Department's core curriculum. In addition, the Undergraduate Educational Policy Committee considered issues surrounding Course VI-A, the use of computers in core subjects, and project study.

**PROGRAM VI-1** Revision of the electromagnetic core subjects was begun this year. In the past, a student was required to take 6.03, Electromagnetic Fields and Energy, but had an option of two out of the following three subjects: 6.06, Fields, Forces and Motion; 6.07; Energy Transmission and Radiation; and 6.08, Statistical Mechanics and Thermodynamics. Beginning next year, he will be required to take 6.03, Electromagnetic Fields and Energy; 6.04, Electrodynamics; and 6.08, Statistical Mechanics and Thermodynamics. The subjects 6.03T and 6.04 will combine coverage of

the old 6.03, 6.06 and 6.07, and an advanced version of 6.06 will be available as an elective.

**PROGRAM VI-2** This program, which began in 1957, was designed for the (then) small group of students who intended to go on to graduate study. Today, the large majority of our students go on at least to the Master's degree, and many continue to the doctorate. Thus, the distinction that was applicable then is no longer valid. A subcommittee of the Undergraduate Educational Policy Committee was set up with Professor R. B. Adler as chairman to re-examine the role and the format of Program VI-2. Student members of the student-faculty committee have played a useful and important role in helping to formulate the problem. No firm conclusions were reached by the end of the term and the study will continue during the next year.

**PROGRAM VI-3** The trial period for the experimental computer science and engineering curriculum has ended. Beginning in 1969, this curriculum will be offered as Program VI-3, a formal curriculum in the Department of Electrical Engineering. Based on the enrollment in the last year, we expect 70 students to enroll in VI-3 this fall.

**COURSE VI-A, THE COOPERATIVE PROGRAM** Professor Reintjes, who has been coordinator of Course VI-A since 1960, has asked to be relieved of this job in order to have more time for his research interests. He is succeeded by Mr. Tucker. The VI-A program is a long-standing feature of the Department of Electrical Engineering, dating back to 1917. It is unique among cooperative programs in the strong coupling between the work assignments and the educational program. This has been achieved by restricting the number of participating companies and laboratories to 11. Today, with the expanding range of topics that interest electrical engineers and the increased desire of students to understand the applications of their classroom studies to real problems, we are considering whether the VI-A program can be effectively expanded to serve more students and whether the number of participating companies should be increased.

**COMPUTERS IN UNDERGRADUATE EDUCATION** Despite M.I.T.'s great wealth of computer facilities, we yet have no service explicitly designed for the needs of our undergraduate students for computation in connection with regularly assigned homework. A special task force, under the chairmanship of Professor Michael L. Dertouzos, has made a study of the Department's needs and has made its recommendations to the administration. There are a variety of ways of implementing the desired service

on the various Information Processing Center's computers. It is proposed that an initial facility of six typewriter consoles, each operating about one hundred hours a week, growing to 16 consoles in about a year, would provide an important level of service to the eight hundred undergraduates in Course VI.

**PROJECT STUDY** A new series of elective subjects will be made available to undergraduates next fall: 6.852-6.858, Project Study. A student will be permitted to join a graduate research group (at the Professor's discretion) and to stay with it for a period of time that may extend over several terms. The student's assignments may range from special readings and problem solving to actual participation in the research work of the group. Grading will be Pass-Fail and continued enrollment for several terms will be encouraged.

**NEW ELECTIVE SUBJECTS** During the past year a number of new undergraduate elective subjects were offered for the first time. The solid-state subjects 6.341 and 6.342 have been modified so that 6.341, Principles of Transistors, serves as a prerequisite for 6.342, Multistage Transistor Amplifiers; 6.343, Computer-Aided Circuit Design; and 6.344, Physical Principles of Solid-State Devices. The 6.342 and 6.343 subjects were taught this year for the first time by Professors James K. Roberge and Richard D. Thornton, respectively, while 6.344 will be introduced next year by Professor David J. Epstein.

Digital systems are the subject of a new sequence: 6.271, Introduction to Digital Systems I; 6.272, Digital Systems Project Laboratory; and 6.273, Introduction to Digital Systems II. The first two of these subjects were taught this year by Professors Richard N. Spann and Donald E. Troxel, and 6.273 will be offered next year by Professor Francis F. Lee. A separate but related subject, 6.257, Switching and Finite Automata Theory, was introduced by Professor Zvi Kohavi. Image Transmission Systems Project Laboratory, 6.723, was offered by Professor Schreiber.

#### **GRADUATE PROGRAMS**

The enrollment of full-time graduate students has been held reasonably constant at approximately 430 for the last few years, primarily due to staff and space limitations within the Department. This year the Department offered graduate admission to 220 new students. Of these, we expect about 160 to register at the beginning of next year. This will yield an enrollment of approximately 445 students in the fall, a small increase over the present enrollment.

The broad range of financial support available for our students is out-

lined in Tables V and VI. Roughly 40 per cent have fellowships, traineeships, or other forms of outside support; 30 per cent are teaching assistants or instructors; and 30 per cent are research assistants. Table VI shows that only about one-third of the fellowships held by our students are awarded by the Department. Since most of the research assistants are supported from Federal funds and since a large fraction (more than 50 per cent) of the fellowship and traineeship funds are derived from Federal sources, uncertainty of Federal funds has created a number of problems relating to financial aid for our graduate students.

**Table V Fellowships, Traineeships, and Outside Support for U.S. and Foreign Students in the Department**

<i>Fellowships awarded by the Department</i>	
Joseph Warren Barker Fellowship	1
The Boeing Company Fellowship	1
Grass Instrument Company Fellowship in Electrical Engineering	1
Industrial electronics (R.L.E.)	1
M.I.T. endowed fellowships	5
Schlumberger Foundation Fellowship in Electrical Engineering	1
<b>Total</b>	<b>10</b>
<i>Government fellowships and traineeships awarded by the Department</i>	
National Aeronautics and Space Administration (NASA)	4
National Defense Education Act (NDEA)	7
National Institutes of Health (NIH)	12
National Science Foundation (NSF) Traineeships	27
<b>Total</b>	<b>50</b>
<i>Outside awards made directly to U.S. students</i>	
American Electric Power Company	1
Atomic Energy Commission (AEC)	2
Bell Telephone Laboratories	12
Canberra Industries	1
Digital Equipment Corporation	1
Hertz Foundation Fellowships	10
Lincoln Lab Staff Associates	4
Massachusetts General Hospital	1
NASA	2
NSF	47
Raytheon Corporation	2
Radio Corporation of America	2
Sanders Associates	1
U.S. Army	2
U.S. Air Force	5
Virginia State Aid	1
<b>Total</b>	<b>94</b>
Foreign Students Supported by their country, industry, or international agencies	13
<b>Grand total</b>	<b>167</b>



**Table VI Financial Support for Graduate Students in the Department of Electrical Engineering**

Type of support	Number supported first term 1968-69
Fellowships, traineeships, and outside support	167
Teaching assistants and instructors	120
Research assistants	120
Own funds	23
<b>Total</b>	<b>430</b>

**THE ELECTRICAL ENGINEERING-RESEARCH LABORATORY OF  
ELECTRONICS COMPLEX**

Plans for the new 160,000-net-square-foot building, to be occupied jointly by the Department of Electrical Engineering and the Research Laboratory of Electronics, are nearly complete. Professor Paul L. Penfield and Dean A. Powers, who was recently named Facilities Officer of the Department, have represented the faculty and staff who will occupy the building in the intricate negotiations with the architects through the M.I.T. Planning Office. Professor Penfield and Mr. Powers have been concerned with details such as space allocation; office, laboratory, and educational space design and arrangement; control of electrical interference; design of social spaces; and allocation of building and laboratory services. Construction on the building is currently scheduled to begin in early 1970, with occupancy approximately two and one-half years hence.

**RESEARCH ACTIVITIES**

The research activities of the faculty and graduate students of the Department of Electrical Engineering are largely, but not entirely, carried on within the administrative frameworks of the following laboratories:

Center for Materials Science and Engineering

Center for Space Research

Electronic Systems Laboratory (E.S.L.)

Project MAC

Research Laboratory of Electronics

Systems Engineering and Operations Research

All of these laboratories are interdepartmental, except for the Electronic Systems Laboratory, which is purely an activity of the Department of Electrical Engineering. In addition to these large laboratory groupings, there are smaller research activities. Summaries of the research in the large laboratories as well as in the smaller groups are presented in the following pages.

## ELECTRONIC SYSTEMS LABORATORY

Faculty, staff members, students, and guests associated with the Laboratory conducted a diversified program of research in the areas of control systems and dynamic systems, computer applications, computer technology and information transfer and display, and aerospace systems and technology. Seventeen projects were active during the year, and are briefly reported below. Detailed information is contained in the "Annual Report of the Laboratory," published separately.

A total of 109 students participated in the Laboratory's activities, 81 at the graduate level and 28 at the undergraduate level. Fifty-seven theses were completed, and degrees earned were as follows: 10 Doctor of Science and Doctor of Philosophy, 8 Electrical Engineer, 27 Master's and 12 Bachelor's degrees. Eleven members of the Department of Electrical Engineering participated in the Laboratory program, including two visiting professors, and three representatives from industry spent all or part of the year here as visiting staff members.

The Project INTREX (Information Transfer Experiments) Machine-Oriented Library System being developed under the leadership of Professors Reintjes and Roberge, has been assembled and is now undergoing tests in preparation for experiments by bona fide users. Alan R. Benefeld and his group of librarians have cataloged 9,000 journal articles in selected areas of materials science and engineering. Richard S. Marcus and his computer programming staff have completed upgraded versions of inputting and retrieval programs.

The Project INTREX Graphical Console, which has been under development for the past two years, is now operating and is being employed to access the computer-stored catalog. The microfiche storage and retrieval system, which makes the full text of all literature contained in the catalog immediately available at the remote consoles, is also functioning. It provides for cathode-ray display of full text as well as hard copy of text in either 35 mm film form or as full-page black-on-white paper copy. Donald R. Knudson and Stephen N. Teicher are currently expanding this system in order to make full text available at several remote stations.

Papers on various aspects of Project INTREX were presented by staff members at the fall, 1968, and spring, 1969, Joint Computer Conferences, and at the fourth Congress of the International Federation for Automatic Control.

Professor Reintjes and Mr. Marcus have extended their work in the application of on-line time-sharing computers to the storage and retrieval of the news. This project, which is conducted under the auspices of the American Newspaper Publishers Association, seeks to enhance the effectiveness of newspaper fabrication through use of modern information

processing techniques. Two symposia for representatives of selected newspapers of the United States and Canada were held at M.I.T. during the year.

The spacecraft radar group, under Professor Reintjes, has concentrated its efforts on an investigation of an instrument that combines an active pulse-type scatterometer with a passive radiometer. When completed, the instrument will have the ability to gather an expanded amount of data concerning the electromagnetic-reflection characteristics of planetary surfaces with a minimum of additional equipment to the scatterometer developed previously by the group. In another radar research program under Laurence R. Swain Jr. and Godfrey T. Coate, work continued on recording, signal-correlation, and display techniques for implementing fine-resolution synthetic-aperture, airborne ground-mapping radar systems. Particular studies have involved the recording characteristics of an experimental relief-image material, the conceptual design of a precision aircraft navigation system using synthetic-aperture radar, and preliminary investigation of an efficient, high-speed digital radar signal processor for such systems.

The display group, under John E. Ward, Deputy Director of the Laboratory, and Albert Vezza, continued work in graphical display systems for man-machine interaction. The E.S.L. Display Console at Project MAC was moved, with its PDP-7 buffer computer, to the Information Processing Center (I.P.C.) to follow the 7094 computer, which was also moved. Work in installing a second E.S.L. Console with PDP-9 buffer at Project MAC was completed except for checkout of the 50,000 bits-per-second telephone link to the I.P.C. 7094, which has just been installed. Software support continued for the E.S.L. Console and the ARDS storage-tube display developed by the group. There are now 14 ARDS in the M.I.T. network, and one was demonstrated at the M.I.T.-T.U.B. (Technical University of Berlin) conference in Berlin last summer via a transatlantic telephone link.

A new program initiated during the year is a joint study with the Urban Systems Laboratory and the Instrumentation Laboratory of a computer-directed, door-to-door bus service (Project CARS). The E.S.L. group under Mr. Ward is studying a digital, computer-controlled radio link for vehicle communication, and is assisting in display considerations.

Professor Dertouzos and the students working with him continued augmentation of CIRCAL-II, a general-purpose, on-line, computer-aided circuit design program. Specific studies included several new analysis techniques that fit within the CIRCAL-II framework, extensions of the definitional capabilities, and a pseudo-user feature for automatic optimization. Doctoral theses by Charles W. Therrien and Huber L. Graham

developed several methods for "tearing" networks to expedite computer solution, and a new technique for the direct analysis of a nonlinear network through recursive decomposition of the network graph. Other work included continuation of the development of the LOTUS program for on-line simulation of block-diagram systems, synthesis of continuous systems, and implicit computation.

The Computer-Aided Design Project, under Douglas T. Ross, Clarence G. Feldmann, and Dr. Jorge E. Rodriguez, continued research on the AED (Automated Engineering Design) family of languages and systems, aided by three visiting staff members from industry. Some 60 preliminary trial versions of the AED System for IBM 7094 and 360, and Univac 1108 computers had previously been distributed to interested companies. The major emphasis during the year was to bootstrap the latest version of the AED-1 Compiler, the AEDJR language-defining system, and the AED Library to the 360 and 1108 for general release, and to provide adequate documentation. The 360 version will be released at a technical meeting in July, and the 1108 version will later be completed by Univac. With the phaseout of Air Force funding, Mr. Ross and his key associates will leave M.I.T. in July to form a company to continue AED developments and applications in the private sector. This completes a 20-year association between M.I.T. and the Air Force, which has included the development of numerical control, the APT language, and AED.

Professor George C. Newton Jr., Associate Director of the Laboratory, Dr. Richard W. Bush, Mark Connelly, and the staff and students associated with them continued study of problems in the guidance and control of underwater vehicles, in the application of real-time hybrid simulation and display technology to the problems of automotive driving task research and safe vehicle design, and in problems of urban transportation. The PDP-1X digital computer, the T-200 analog computer, and the Adage AGT-30 Graphics System (which includes a digital computer) have been used for these simulations. A link between the PDP-1X and the AGT-30 was designed to bring the computing power of both machines together to permit larger simulation problems, but this has not yet been implemented. Mr. Connelly completed a study of future urban transportation systems and road networks for the Greater Boston area, and assisted the NASA Electronics Research Center in the design of a hybrid computation facility based on a PDP-1X computer, for real-time simulation.

In the area of control theory, Professors Michael Athans, Roger W. Brockett, Fred C. Schweppe, Ian B. Rhodes, and Jan C. Willems, with Professor Lawrence B. Evans of the Department of Chemical Engineering and a team of 49 graduate students, continued their investigations in

nonlinear systems theory, optimization techniques, distributed parameter systems, optimal design and control of bulk polymerization processes, differential games, and computational algorithms. These techniques are being studied in the context of a number of real-world problems, including power generation and distribution systems, airtraffic control, chemical process control, signal design for radar and communications systems, and aerospace and high-speed transport vehicles.

In other research projects, Professor Roberge continued study of low-power circuitry for aerospace applications, exploiting particular characteristics of solid-state devices. A long-standing program in thin-film active devices using gallium arsenide FET structures, and thin-film memories using radio-frequency reading and writing techniques was brought to a close with publication of final reports.

Both faculty and staff were active in presenting the results of their research at various meetings of the professional societies, and participated in the direction of society activities. Professor Athans continued to serve as Associate Editor of *Automatica* and was elected a member of the Administrative Committee of the Institute of Electrical and Electronics Engineers (I.E.E.E.) Automatic Control Group. Professors Athans and Schweppe also served on various American Automatic Control Council (A.A.C.C.) and A.C.T. committees. Professor Newton and Mr. Ward are members of an A.A.C.C. committee planning the 1975 Congress of the International Federation on Automatic Control, tentatively scheduled for M.I.T. Mr. Ward served as Vice Chairman of the 1969 Spring Joint Computer Conference, held in Boston in May. Professor Athans was the recipient of the first Terman Award of the Electrical Engineering Division of the American Society of Engineering Education (A.S.E.E.).

Details of individual research programs were reported in 40 technical reports issued by the Laboratory during the year.

#### RESEARCH LABORATORY OF ELECTRONICS

In the Research Laboratory of Electronics (R.L.E.), faculty and students from a dozen academic departments conduct basic research covering a large range of topics, most of which fall into one of three broad categories, designated as general physics, plasma dynamics and communication sciences.

The research in general physics includes a variety of activities, many of which are based on atomic resonance phenomena. The experimental techniques required to observe these basic properties of matter and to exploit them in engineering applications span most of the electromagnetic spectrum from radio wavelengths to X rays. Other experimental require-

ments include the use of extremely high frequency vibrational waves, the use of liquid helium temperatures, and extensive use of computers.

The major goal of the plasma dynamic program is generation of basic understanding of phenomena in ionized gases and in solids in ways that are relevant to problems such as controlled fusion, space physics, and collective phenomena in solids. The research includes methods of producing highly ionized plasmas by electron beam injection, high-powered lasers, microwaves, low-pressure arcs, and so forth.

The research in communication sciences spans a broad range of topics pertinent to communication processes in man-made and living systems, as well as interactions between them. Fundamental studies of signals and systems are coupled with various applications such as speech and picture transmission, seismic detection, and optical communication channels. A major portion of the effort is related to the life sciences. A combined program of research and training in communications bio-engineering includes areas such as communications biophysics, neurophysiology, cognitive information processing, and speech communication. Much of this work concerns the sensory or perceptual mechanism and the related program in linguistics seeks to improve our understanding of languages, which form the basis for communication.

The Department of Electrical Engineering is the largest participant in the research activities of R.L.E. Currently, about 55 of the Department's faculty, 125 graduate students and 50 undergraduates are engaged in a variety of projects spanning most of the research categories mentioned above.

During the last year, 17 doctoral, one Engineer, 38 Master of Science, and 33 Bachelor's theses in electrical engineering were based on research supported by R.L.E.

The following paragraphs summarize some of the R.L.E. research activities in which electrical engineering faculty members and students have participated during the past year.

The microwave spectroscopy group, supervised by Professor Kyhl of the Department of Electrical Engineering and Professor Malcom W. P. Strandberg of the Department of Physics, has made measurements of the noise figure of thin film superconducting bolometers evaporated on solid sapphire substrates. These measurements indicate an excess noise figure of about 15 decibels above the theoretical limit set by thermodynamic fluctuation theory. The mechanism of noise generation is not known, but the noise is quenched by a perpendicular magnetic field of a few Gauss.

The faculty members conducting research in radio astronomy include Professor David H. Staelin of the Department of Electrical Engineering, and Professors Alan H. Barrett, Bernard F. Burke and Richard M. Price

of the Department of Physics. Of the 14 graduate students in the group, seven are from the Department of Electrical Engineering. The research activities include the following lines of investigation: (1) spectral radio emission from hydroxyl (OH) radicals that originates from infrared stars; (2) radio emission by water (H<sub>2</sub>O) molecules from selected regions of the galaxy; (3) a survey of approximately two hundred ionized hydrogen regions in the galaxy, allowing dynamical studies of the large-scale spiral structure through the ionized component of interstellar gas; (4) study of pulsating radio sources (pulsars). Professor Staelin has been designated as the principal investigator of a microwave experiment selected for inclusion in the payload of a future NIMBUS meteorological satellite. The experiment is designed to yield the temperature profile and water vapor content of the atmosphere.

The solid-state microwave electronics group, under the direction of Professor Robert P. Rafuse and Dr. Donald H. Steinbrecher, is continuing its activities in the area of high dynamic range instrumentation with the completion of a special test set allowing the detection and measurement of distortion products as much as 120 decibels below the desired signal levels. The test set sweeps from 2 to 50 MHz and displays the spectrum as a typical log-amplitude versus frequency pattern. Work is continuing on the all solid-state, 60-GHz receiver with excellent preliminary results on the local oscillator and a 7 decibel conversion loss in the first model of the mixer. The impatt diode studies are continuing, and a large-signal model has been derived (from small-signal measurements) which describes the oscillating behavior with harmonic-impedance control in excellent agreement with experimental evidence. The group is continuing its theoretical and experimental work, designed to discover the fundamental performance limits of solid-state devices and the circuit imbedment procedures necessary for the realization of such performances.

The gas laser group of Professor Haus and his students are continuing the work on laser interaction in carbon dioxide at a wavelength of 10.6 microns. They have demonstrated theoretically and experimentally that gain saturation in a CO<sub>2</sub> laser with optical beam diameters of four millimeters or less is strongly affected by spatial diffusion of excited CO<sub>2</sub> molecules into the beam and of de-excited CO<sub>2</sub> molecules out of the beam. A CO<sub>2</sub> laser oscillator cavity-dumping scheme has been built that produces pulses of the order of 5 kilowatts peak with less than 5 nanoseconds rise times. These pulses are used to study the amplification process in carbon dioxide within short times comparable to the inverse bandwidth of the lasing medium and at intensities which lead to appreciable depletion of the inversion in the medium.

Professors Haus and Penfield have continued their work on Electrodynamics of moving media, resulting in a relativistic formulation for quadrupolar media.

The active plasma systems group, under the supervision of Professors Louis D. Smullin, Abraham Bers (absent), Keith I. Thomassen, Ronald R. Parker, and Richard J. Briggs, continued basic experimental and theoretical studies of plasma dynamics in a number of areas.

Work by Professor Smullin, Joseph A. Mangano, and Rulon K. Linford on the generation of energetic mirror-confined plasmas by high-power electron beams has concentrated on measurements of the radio-frequency spectra emitted by such discharges, and on the measurement of the energy of escaping ions. A low-power beam-plasma experiment performed by Professor Bers and Bruce R. Kusse used a spiraling electron beam to study instabilities in this configuration, which is common to several controlled fusion experiments.

Professors Parker and Thomassen successfully stabilized a rotating instability that occurs in a magnetically confined dc discharge by the use of active feedback control. This method of plasma stabilization is of considerable interest at the present time in connection with its possible application to fusion plasmas.

An experimental and theoretical study of spontaneous cyclotron frequency emission from tenuous hot electron plasmas, conducted by Professor Bers, Professor Briggs, and Carlton E. Speck, has shed light on the very efficient coupling between energetic electrons and microwave fields in highly nonuniform magnetic fields.

All of the plasma groups, comprising physicists, electrical engineers and nuclear engineers from R.L.E., have started a collaborative study with the Francis Bitter National Magnet Laboratory to design toroidal plasma devices suitable for generating a controlled fusion plasma.

The communications biophysics group, under the direction of Professors Walter A. Rosenblith and William M. Siebert, continued its efforts to obtain a better understanding of sensory processes by combining electrophysiological and behavioral experiments with modern data processing and the analytical methods of physical science.

Research in psychophysics, supervised by Nathaniel I. Durlach, has been strengthened by the addition of Professor Julius L. Goldstein to the research staff. Experimental and theoretical work in this area has led, during the past year, to the development of two new theories. The first is based on a particular assumption about a limitation on the way the brain makes use of timing information in the auditory nerve, and is applicable to problems of interaural discrimination, binaural detection, and contralateral cueing. The second theory concerns intensity resolution,



and unifies the results from a wide variety of experiments on detection, discrimination, identification, and scaling of sound intensity.

The studies of neuroelectric correlates of behavior, under Dr. Robert D. Hall, have recently been focused on the problem of tracing central influences on the motoneurons that mediate eyelid responses in the rat during conditioning. Professor Stephen K. Burns and his students have developed several instruments for the characterization and display of ectopic heart beats appearing in the electrocardiogram. Visiting Professor Richard W. Henry and his students have continued their studies of central modulation mechanisms in the proprioceptive control system of the crayfish abdomen. A study of chromatic adaptation in single units of the optic nerve of the ground squirrel was completed by a student of Professor Rosenblith. Studies of baroreceptor firing patterns and of other aspects of the mammalian blood pressure regulatory system were carried out by Professor Peter G. Katona with Dr. G. Octo Barnett of the Massachusetts General Hospital. During the latter half of the year, Professor Lawrence S. Frishkopf joined the group and established a new laboratory facility for the study of hair cells in the lateral line organs of fish and amphibia.

A number of experimental projects were carried out by members of the group in the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary under the general direction of Dr. Nelson Y. S. Kiang. Professor William T. Peake and his students have carried out further investigations of mechanical motions in the ear utilizing the Mossbauer effect. Jointly with Professor Peake, Professor Thomas F. Weiss has obtained new results with microelectrodes on the variations of the microphonic potential with location in the cochlea. Professor Michael L. Wiederhold has continued his studies of the olivocochlear bundle and Professor John J. Guinan has shown further correlations between the anatomical and physiological properties of cells in the superior olivary complex.

Professor Jerome Y. Lettvin and his associates in the neurophysiology group report new results on the properties of neural networks. As part of a study which has been conducted during a period of four or five years, Stephen A. Raymond's doctoral thesis (submitted to the Department of Biology) examined the effects of axon bifurcation on pulse sequencing. Professor Lettvin and Dr. Shin-Ho Chung had previously shown that multiplexing of information does occur in nerve fibers, and Dr. Raymond's work indicates that the basis for handling multiplexing exists in nerve fibers. Robert J. Bobrow, a graduate student in the Department of Mathematics, has used Dr. Raymond's results to make spatial displays that preserve the multiplexed information.

The cognitive information processing group, under the direction of Professor Murray Eden, has continued its studies of the ways by which humans process visual information, and concomitant studies on mechanical ways to perform similar cognitive tasks. During the past year substantial progress has been made by Professors Samuel J. Mason, F. Lee, and Troxel and their students on the development of a reading machine for the blind. The current version can scan text pages of conventionally printed books and can produce intelligible synthetic speech at normal human speaking rates.

Professor Eden and Dr. Oleh J. Tretiak, with their associates and students, have pursued a variety of particular image processing problems of direct relevance to clinical pathology and morphology. Human leukocytes have been successfully classified with a program developed by Dr. Ian T. Young. Dr. James E. Green has shown that many optical and morphological properties of individual erythrocytes can be quantitatively determined by automatic computation based on photographic images of standard peripheral blood smears. Dr. Robert R. Archer has shown that certain morphological aspects of the growth pattern of leaves can be simulated by a model in which a vascular network is imbedded in an elastic continuum.

Professors Thomas S. Huang and Schreiber and their students have devised a procedure for producing holographic filters with the aid of a computer. They have also found that a picture transformed into the Fourier domain can be described by a code with somewhat less than one bit per picture sample point. This represents a very substantial improvement in the bandwidth requirement for the transmission of visual information.

Members of the speech communication group, under direction of Professors Kenneth N. Stevens, William L. Henke, and Dennis H. Klatt, have been involved in further studies of the properties of speech events and of the mechanisms for human generation and perception of these events, particularly the perception of the temporal aspects of speech. The capabilities of a digital computer facility for the study and simulation of speech events have been expanded, and this facility has been used to develop procedures for the automatic recognition of simple spoken words, for the identification of attributes that identify particular talkers, for the synthesis of speech, and for the visual display of speech sounds. Among the results obtained in the continuing studies of the production and perception of speech by children has been a description of the kinds of intonation patterns that a child is able to produce during the early stages of language development.

The information processing and transmission group has been exploring

optical communications channels and source coding techniques. Professors Estil V. Hoversten and Kennedy and their students are looking at the use of channel-sounding and feeding techniques to improve optical communication through a turbulent atmosphere. Optimum receivers for quantum channels and the transition from classical to quantum channel models are also under investigation. Professor Robert G. Gallager published a book, *Information Theory and Reliable Communication*, a systematic presentation of information theory which contains many recent research results. He has also continued research on rate-distortion theory. Student thesis work is in process on analog modulation and on cascaded and interleaved tree codes. Professor Peter Elias has been working on quantization.

Professor Donald E. Nelsen and his students have been concerned with random processes that occur in regenerative switching circuits, such as the flip-flop and Schmidt trigger. Models that relate switching-time randomness to the more fundamental shot, thermal, and low-frequency noise processes that occur in these circuits are being investigated. Also being studied is the relationship of these processes to first passage time processes.

#### PROJECT MAC

Many members of the Department of Electrical Engineering conduct their research in Project MAC, an interdepartmental laboratory for computer science and engineering. Twenty-three members of the electrical engineering faculty and about 70 students, graduate and undergraduate, are working with the Project MAC staff and colleagues from other departments on diverse aspects of the problem of intellectual interaction between men and computers.

At the beginning of the year, Professor Robert M. Fano resigned as director of Project MAC in order to devote his time to teaching and research on the problems of computers and society. He has been succeeded by Professor J. C. R. Licklider.

In most of the research of Project MAC, there is a blending of theory and experiment and of science and engineering. One learns about the nature of complex informational processes by designing and creating such processes, perfecting them, using them, evaluating them, and then going back to modification or redesign.

For five years, the largest undertaking in Project MAC has been the development of a new and advanced time-sharing computer system called MULTICS (Multiplex Information and Computation Service). This effort has been a joint one with the General Electric Company and the Bell Telephone Laboratories. Project MAC's part of the work has been di-

rected by Professor Fernando J. Corbato. Professors Jerome H. Saltzer, Robert M. Graham, Elliott I. Organick, many students, and about 25 members of Project MAC staff also have contributed strongly to the MULTICS effort, which has been an ambitious pioneering thrust into the realm of very complex "hardware-software" systems.

As 1968 turned into 1969, the MULTICS project reached the crown of its long, steep hill. Advances became easier to make, and they came more quickly. Now the system is sufficiently complete and reliable for use by knowledgeable and "friendly" system programmers accommodating as many as 20 simultaneous users, and limited by telephone interface equipment. According to present plans, MULTICS will be available for general use on October 1, 1969. It will be a very comprehensive multi-access computer system, and it will offer unprecedented facilities for the development of very large systems of programs by teams of programmers, for controlled sharing of procedures and data, communication among users, and for research on the operation of multi-access computer systems.

According to most conventional measures, MULTICS constituted about half of Project MAC during the past year. The other half was made up of about a dozen smaller research programs, most of which involved electrical engineering faculty and students.

Professor Fano has begun to study the impact of computers on society. He is chairman of the Panel on Computers and Society of the Committee on the year 2000 of the American Academy of Arts and Sciences.

In the Artificial Intelligence Laboratory of Project MAC, Professor Marvin L. Minsky, Visiting Professors Chao K. Chow, Edward Fredkin, Hosakere N. B. Mahabala, and their colleagues made further steps toward demonstration of a programmed computer system capable of working constructively in a poorly organized environment, for example, examining a complex structure made of blocks and building another like it out of blocks scattered about the floor. Professor Adolfo Guzman Arenas' scene-analyzer program yielded a new insight into complex pattern vision and provided the basis for a new theory of human visual analysis. The Greenblatt chess-playing program advanced to Class C. The Charniak problem-solving program solved calculus problems stated in ordinary English.

With Professor William A. Martin of the Sloan School of Management, Dr. Carl Engelman of the MITRE Corporation and several students, Professor Joel Moses set out to combine a number of existing and projected computer programs into a computer-based mathematics laboratory. Professor Moses' symbolic-integration program advanced in capability; it can solve problems in integration — not merely by adding up numbers, but by manipulating the symbols as one must to solve indefinite integrals

— about as well as a good mathematician. The mathematics laboratory is progressing.

Professors John M. Wozencraft and Arthur Evans reached a consolidation point in their study of the conceptual foundations of computer programming. Their efforts yielded a pedagogically oriented algorithmic language (PAL) that sets forth basic programming concepts in clear relief, and their approach is documented in the subject notes for 6.231, Programming Linguistics. Professor Evans has now embarked upon a program of research on “extensible programming languages,” that is, languages that are simple when you learn them yet easy to extend to cope with complex problems that you encounter later.

Professor John J. Donovan and a large group of students covered a wide enough range of topics to constitute a laboratory of computer science and engineering on their own. They advanced Professor Donovan’s theory of canonic systems and proved several theorems about capabilities of programming languages. They made good progress on the development of a new and faster operating system for the very widely used IBM 1130 computer. And, with Professor Malcolm M. Jones and some of his students in the Sloan School of Management, they designed a new simulation language incorporating the best features of several older simulation languages and introducing them into the context of the new procedure-oriented language, PL-1. Working on theory of computation and theory of automata, Professor Kohavi developed some fundamental ideas about how to test complex digital systems for malfunctions.

One of the most pressing problems in the computer field stems from the fact that programs and data prepared for use in one computer system ordinarily turn out to be usable, without considerable ad hoc modification, in another. Professors Jack B. Dennis and Fred L. Lucconi and their students have studied the prerequisites, in the design of computer systems, for program and data interchange.

TEACH, an interactive computer program that teaches elementary programming, has been developed by Professors Joseph Weizenbaum and Robert R. Fenichel, with Jerome C. Yochelson, in a joint project of the Education Research Center, the Department of Electrical Engineering, and Project MAC. Last year, TEACH was used in one section of the introductory programming subject, 6.47.

Although Project MAC’s main involvement in the educational process is implicit in its faculty-student research activities, it plays a role also in the development of subjects of instruction (all the subjects of the computer-science core curriculum, and others), and it offers project laboratories. Professor Donovan conducted a Project Laboratory in Software Development this year. Dr. William R. Sutherland of the Lincoln Labora-

tory, Dr. Judah L. Schwartz of the Education Research Center, several staff members, and Professor Licklider introduced a Project Laboratory in Computer Graphics.

A fuller discussion of Project MAC is given in the Provost's section of this volume.

#### POWER SYSTEMS ENGINEERING GROUP

During the past year, the faculty, students, and staff of the power systems engineering group have strengthened and expanded their research and educational activities in the area of power generation, transmission and utilization. Faculty members active in this group are Professors Herbert H. Woodson, Charles Kingsley Jr., Gerald L. Wilson, and Scheweppe, and Professor Joseph Gerstmann of the Department of Mechanical Engineering.

During the year, the activities of the group have involved seven doctoral candidates, 15 Master of Science candidates, and two Bachelor of Science students, as well as eight undergraduates doing laboratory projects for academic credit. One doctoral thesis was completed, as were nine Master of Science theses and one Bachelor of Science thesis.

The research activities of the group are focused in the following major areas:

1. A study of the physical processes that occur when outdoor insulation flashes over due to the presence of contamination
2. A study of the reasons why abnormal voltages occur on extra high voltage (EHV) transmission systems when the iron cores of transformers and reactors saturate
3. A study of the use of computers in the central control of interconnected power systems to improve reliability
4. A study of the feasibility of making more accurate models of power system components by making physical scale models based on electromagnetic and electromechanical scaling concepts
5. A study of the reasons for unexpected pressure pulsations in the penstocks of pumped-storage hydro-installations.
6. A study of the use of superconducting field windings in large synchronous machines such as turbogenerators and synchronous condensers. This project is being undertaken jointly by members of the power systems engineering group and members of the Cryogenic Engineering Laboratory of the Department of Mechanical Engineering.
7. A study of the optimal design of dry cooling towers which focused on physical limitations to possible cost reductions
8. A formulation of a generalized reduced-order boiler model for use in central computer control of power systems

9. The development of a computer program to solve for electric fields in two dimensions in the presence of complicated conducting and dielectric boundaries

10. A study of a new method of arc interruption in magnetic circuit breakers

During the fall term, Professors Wilson and Kingsley taught 6.551, Power Systems Engineering I, to about 15 students. During the spring term, Professor Wilson taught 6.552, Power Systems Engineering II, to about eight students. In addition to these formal subjects, additional opportunities for academic work were afforded through 6.715, Power Systems Engineering Project Laboratory. During this year, eight undergraduates availed themselves of the opportunity to do project lab work with this group.

During the year, the power systems engineering group continued to receive substantial financial and manpower support from the American Electric Power Service Corporation. Lectures were given in our graduate subjects by Melvin I. Olken, Paul Dragoumis, and Antony F. Gabrielle of American Electric Power.

In conjunction with the research and teaching activities of the group, field trips were made to the Bratton Point Generating Plant of the New England Electric System and to several engineering activities at the Schenectady plant of the General Electric Company.

#### LABORATORY FOR INSULATION RESEARCH

The growing of pure ice single crystals and their detailed investigation has led to a fundamental reappraisal of our understanding of proton transfer mechanisms. The work is being extended to doped ice crystals, the influence of dislocations and phase transitions, the transfer of charges through surface layers, and into the liquid state. The results are not only of principal interest for solid-state physics and chemistry, but may contribute to a better understanding of problems in cryobiology, glaciology, and thunderstorm research.

The work on the dielectric properties of materials at very high temperatures continues. William B. Westphal is in charge of the dielectric measurements group. His advice is sought by staff and students throughout the Institute and by many outside agencies. Professor Arthur R. von Hippel guides the research program, acts as consultant to the Office of Naval Research, and has been invited to give the opening lecture at the International Conference of Ferroelectricity in Japan. A graduate subject, From Atoms Toward Living Systems, was given during the spring term.

## HIGH-VOLTAGE RESEARCH LABORATORY

For some years the High-Voltage Research Laboratory, with the cooperation of other biological and medical research groups, has applied low megavolt electrons to the sterilization of tissue for banking and subsequent surgical use. The irradiation techniques and the clinical observations on these irradiated structures, which include aorta, bone, heart valves, arteries, and blood components, were recently reported by Kenneth A. Wright at an International Atomic Energy Conference in Budapest on "The Use of Ionization Radiation for Sterilization and Preservation of Biological Tissues." This program made use of the 3-MeV Van de Graaff electron accelerator, which is soon to be upgraded to 5-MeV operation with the aid of a grant from the Fannie E. Rippel Foundation.

The laboratory continued its innovative work on the injection of megavolt electrons into the skin and subcutaneous tissue for the control of extensive areas of superficial tumors. During the year, 68 new patients with widespread skin involvement were treated with two- to three-megavolt electrons. These constitute a new therapeutic agent with a more efficient and improved distribution of dose in depth. This in turn leads to lessened skin reactions and to the virtual absence of systemic effects even when the entire body surface requires treatment. This investigative program is sponsored by the Damon Runyon Memorial Fund for Cancer Research.

Preparations have been completed for the installation of the new 3-MeV Van de Graaff X-ray source for cancer therapy. This acquisition, also aided by the Fannie E. Rippel Foundation grant, will replace the older of the two 2-MeV X-ray sources used daily in the treatment of patients in the cooperative program with physicians of the Lahey Clinic Foundation.

Dr. Magnus I. Smedal and Dr. Ferdinand A. Salzman have the medical responsibility for this physicoclinical program. Novel ways of localizing the absorbed X-ray radiation dose in the invaded tissue regions and of selectively protecting adjacent normal structures are being developed, reduced to therapeutic practice, and carefully followed for comparative clinical results.

The Laboratory continued its studies on the electrical processes that influence the voltage-insulating performance of high vacuum. A doctoral investigation by Chathan M. Cooke is concerned with the intermediate residual pressure region, termed "semivacuum," in which the optimum insulating strength is realized.

The need for more economic solutions for underground high-voltage power lines in populated regions is now widely appreciated. The Laboratory has further advanced its investigations on the feasibility of utilizing



the electronegative gas SF<sub>6</sub> at elevated pressure as the principal voltage-insulating medium for such underground lines. Less concerned with hardware, these studies are directed at understanding and controlling those factors which affect adversely the insulating performance. A Master's thesis was completed by Armin Diessner on the effects of free conducting particles in a coaxial compressed-gas-insulated system. A grant from the Edison Electric Institute supports this work.

Other aspects of the program include a doctoral investigation to develop a new calorimetric method of electron dosimetry and to develop an exceedingly compact source of low-megavolt electrons for therapy.

The work of the High Voltage Research Laboratory is also supported by grants from the Lahey Clinic Foundation and the Biddle Foundation.

#### SYSTEMS ENGINEERING AND OPERATIONS RESEARCH

The systems engineering group continues its research on theoretical and applied topics, with an increasing number of projects motivated by a growing concern with problems of the public domain.

James S. Kakalik, in his doctoral dissertation supervised by Professor John D. C. Little of the Sloan School of Management, is investigating the use of Markovian decision theory to determine optimal control policies for certain classes of service facilities. Working with Professor Jeremy F. Shapiro, also of the Sloan School, Kianianthra M. Chandy is presently completing his doctoral dissertation on the parametric decomposition of linear programs.

Working primarily with Professor Howard Raiffa of Harvard University, Ralph L. Keeney has completed his doctoral dissertation on the assessment of preferences in multidimensional spaces. He demonstrated interesting applications for decision related to blood banking, the routing of telephone calls, and the dredging of the Cape Cod Canal. Amedeo R. Odoni, working with Professor Robert W. Simpson of the Department of Aeronautics and Astronautics, has developed a class of models to consider strategies for the more effective control of the queues of arriving and departing aircraft at large, active airports.

Professor Alvin W. Drake and several electrical engineering graduate students have been developing research areas in the quantitative modeling of public systems.

John B. Jennings and Stephen V. Tang have been concerned with operational aspects of blood-banking systems, from activities within an individual hospital through to the implementation of regional systems. Acting in cooperation with the Project RAND team for the New York City Administration, Richard C. Larson is completing his doctoral dissertation on the allocation and control of police patrol activities. Joseph

Ferreira is modeling particular issues relevant to national strategies for vehicular insurance. This work, relating three mutually unhappy participants — the motorist, the insurance industry, and the government — is being performed in close liaison with the U.S. Department of Transportation's Task Force on Insurance. Keith A. Stevenson is attempting to develop a practical methodology for the evaluation and efficient improvement of emergency ambulance services in urban areas.

The annual report of the M.I.T. Operations Research Center presents in considerable detail the activities of the systems engineering and operations research group.

#### CENTER FOR SPACE RESEARCH

Professors Davenport, John V. Harrington, and Robert D. Yates, and graduate students Gerald L. Dutcher and Peter Alexander have been working on the development of a complete statistical characterization of the communication channel for a propagation path through an ionized medium in general and the solar plasma in particular. This problem has been motivated by space physics experiments, such as the measurement of the interplanetary electron density, by the M.I.T. Center for Space Research Sunblazer probe and several relativistic experiments proposed by Professor Irwin I. Shapiro of the Department of Physics.

A fairly complete scattering function description of the solar plasma channel has been developed, and the channel statistics have been determined for most regions of interest. These results were then used to predict the detection and estimation performance of the Sunblazer receiver.

#### STROBOSCOPIC LIGHT LABORATORY

This year saw a greatly increased interest by students who are especially oriented to photography due mainly to the addition of Bruce E. DePalma, as Visiting Lecturer. The students in his classes have had an opportunity to conduct some of their experimental work at the Polaroid Company's research laboratory.

A special summer seminar on techniques in highspeed photography was held in June, 1968. This was the fourth and final of a series that began in 1960, on alternate years. The attendance for each session averaged 70 students, who came from industry, government laboratories, and universities.

An exhibit of pictures, made by 6.202 students during the current year, was placed in the Stratton Student Center, May, 1969, and also at M.I.T.'s Open House.

The Strobe Lab continues to furnish lectures for open house displays and for other lectures such as the M.I.T. Children's Lecture for the benefit of the Technology Nursery School.

Twenty freshmen collaborated in an undergraduate seminar on strobe light theory and application, under the leadership of Professor Harold E. Edgerton. This year has seen special efforts directed towards the study of shockwaves from bullets that have velocities above and below that of sound in air.

#### PARTICLE OPTICS LABORATORY

The Particle Optics Laboratory of Professor Charles K. Crawford is studying projects relating to both theoretical electron and ion optics and to practical applications of this technology. During the past year, Dr. Friedrich G. Ruedenauer joined the group as a Research Associate with the primary responsibility of designing ion sources.

A program has been initiated to design an ion-microprobe mass spectrometer to be used in analyzing trace impurities in very small samples and in the study of very thin surfaces. This instrument will be unique in that a microfocus sputtering ion beam and a high-resolution mass spectrometer will be combined with a scanning electron microscope. The intent is to use a field-emission type scanning electron microscope for nondestructive high-resolution observation of samples, while the mass spectrometer would be used for high-sensitivity destructive analysis of specific areas. It should be possible to achieve trace analyses much more sensitive than are obtainable with electron X-ray-microprobe techniques. Because the ion beam gradually sputters through the sample, it will also be possible to study surface layers and to measure impurity concentration gradients with a depth resolution of better than 100 angstroms. The instrument is being designed to allow simultaneous operation of both beams; ultra-high vacuum is being provided.

A continuing project concerns the design and fabrication of ion sources suitable for ion implantation and for the study of ion-induced chemical reactions in thin films. Uniplasmatron sources have been constructed of a modified Magnusen type, which are compact, and which can operate at temperatures above 1,000°K (total power consumption less than 100 watts). Heavy-metal ion beams, with currents in the 1 micro-ampere range have been obtained for materials like lead. The vapor pressure of the element to be ionized is controlled by use of a separate high-temperature oven located behind the source; the source temperature itself is controlled independently. One of the sources is currently being used to study reactions induced in photoresists by ion bombardment.

Cross sections for the single and multiple ionization of metal vapors by electron impact are being measured using a large quadrupole mass spectrometer. Current work is concentrating on the ionization of various

species found in carbon vapor; the work is complicated by difficulties of determining which ion results from which parent species. During the past year a high-temperature, electron bombardment, water-cooled Knudsen cell was designed and constructed, an atomic beam mechanical chopper was added, an electron multiplier of improved design was installed, and improvements were made in the system electronics.

A program to explore the feasibility of using small-diameter electron beams as current and voltage sources to test electronic microcircuits is continuing. The idea is to focus many (or at least several) 1-micron diameter electron beams onto a microcircuit and to use the secondary electron spectra emitted by the various contact pads under electron bombardment as a means of determining the surface electrical potential of each pad being bombarded. By coding each incoming beam with a low-amplitude high-frequency modulation and using synchronous detectors, it should be possible to measure all potentials simultaneously with a single secondary electron spectrometer. Voltage signals could then be injected using feedback. A desirable feature of this technique is that it appears to be compatible with the new fabrication methods based on particle-induced chemical reactions now being developed. Combining these two technologies in the same vacuum system should make possible very large arrays of components, since discretionary wiring could proceed concurrently with testing. A secondary-electron spectrometer was constructed during the past year, however it is not yet operating properly. The design of improved spectrometers is being undertaken.

#### CONTINUUM ELECTROMECHANICS

Although the continuum electromechanics group has a continuing interest in a range of interactions between electromagnetic fields and continuous media, its major activity centers around electrohydrodynamics. From March 31 to April 2, 1969, the group was host for an International Symposium of Electrohydrodynamics sponsored by the International Unions of Theoretical and Applied Mechanics and Pure and Applied Physics. This meeting, which brought together scientists and engineers with a wide range of interest and background, served to point out the diversity of this developing field of electrohydrodynamics.

Under the supervision of Professor Melcher, effort is being made further to define and explore physical situations in which electromechanical macroscopic coupling between fields and fluids is essential. Four areas of particular interest have been investigated:

1. The development of continuum feedback control techniques making use of scanning electron beams as a means of both sampling the motions of a fluid and of feeding back a force to control Rayleigh-Taylor instability.

Mathematical techniques have been developed to represent the effects of spatial sampling; this work has proved to be useful in connection with current efforts to stabilize plasma equilibria.

2. The collective dynamics of charge carriers dominated in their motions by inertia. Mathematical models in this area are, in some respects, similar to those for electron beams. However, instead of electrons, interest is in charged macroscopic particles, such as liquid drops. Both steady flows and their stability are of interest, with emphasis given to the generation of macro-electric fields. Applications range from power generation to particle precipitation and thunderstorm electrification.

3. Electrohydrodynamic polarization forces have been demonstrated to provide a mechanism for making "wall-less" pipes, wherein a liquid flows along a structure, much as it does in any ordinary pipe, but there are no physical walls. Emphasis has been given to the effects of fluid rotation on the dynamics of these flows, and to means of inducing flow by making practical use of ion-drag pumping. Applications here include heat pipes.

4. Work has continued on electroconvective instabilities, especially at interfaces, where they give clues as to the detailed electrical structure of the interfaces and electrical conduction therein.

#### CENTER FOR MATERIALS SCIENCE AND ENGINEERING

Some 20 members of the electrical engineering faculty along with about 60 graduate students are engaged in research on electronic materials and devices within the Center for Materials Science and Engineering.

The Crystal Physics Laboratory, under the direction of Professor Alexander Smakula, is continuing the study of optical and ferroelectric crystals. New complex oxide and fluoride laser host crystals, including  $\text{Ba}_2\text{MgGe}_2\text{O}_7$ ,  $\text{CaY}_2\text{Zn}_2\text{Ge}_2\text{O}_{12}$ , and  $\text{LiYF}_4$ , have been grown and fluorescence and energy transfer studied for various rare earth activators and sensitizers. Glass-to-crystal transitions have also been studied in these systems. Crystals of  $\text{Bi}_4\text{Ti}_3\text{O}_{12}$  with a complex layer structure and of  $\text{Gd}_2(\text{MoO}_3)_4$  have been grown for ferroelectric studies with applications to optical switching, and Raman spectroscopy has been applied to the study of soft-mode vibration in these and other ferroelectric crystals. Some thiospinels such as  $\text{CdIn}_2\text{S}_4$  have been grown by chemical transport reaction and their optical properties studied. Low-temperature dielectric measurements have been used for a systematic study of n-type, p-type and compensated Si crystals and characteristic differences have been found.

The microwave and quantum magnetism group, directed jointly by Professors Epstein and Frederic R. Morgenthaler, is concerned primarily with cooperatively ordered magnetic and dielectric materials and their

applications to microwave and optical devices. Professor Morgenthaler and his students continue to be concerned with the field of microwave magneto-ultrasonics. The primary focus is on spin-elastic wave interactions in ferromagnetic and antiferromagnetic single crystals. Interest is warranted because of the fundamental information which can be obtained from magnetic and/or ultrasonic spectroscopy and because these interactions make possible novel microwave devices such as magneto-elastic wave parametric amplifiers, tunable delay lines, and pulse compression filters. Work during the past year has included infrared laser probing of magneto-elastic waves in yttrium-iron-garnet (YIG); double resonance in the antiferromagnet  $\text{RbMnF}_3$  has been successfully carried out, and the interaction between nuclear and electron resonance modes studied under a variety of conditions. Phonon excitation of nuclear resonance modes in the same material via quantum mechanical exchange interaction has been analyzed and the experiments are under way. Also continuing are theoretical and experimental studies of the coupling effects among phonons, magnons and photons at interfaces between magnetic dielectrics. Professor Epstein and his students have been working on problems relating to magnetic loss in ferrimagnetic garnets. The temperature and frequency dependency of several different loss mechanisms have been studied and, for one mechanism, it has been possible to correlate magnetic data with electrical transport studies. Currently, the photomagnetic effect (a change in magnetic properties induced by light) is being used as a tool for the study of low-temperature losses in silicon-doped yttrium-iron garnet. Several ferroelectrics which have interesting electro-optical properties are being studied and work is being started on a number of semiconducting ferroelectrics which have potential application to devices that combine semiconducting and optical behavior in novel configurations.

Within the semiconductor materials and devices group, Professors Thornton, R. B. Adler, Robert H. Rediker, Arthur C. Smith, Bruce D. Wedlock, Floyd O. Arntz, John S. Moore, Daniel L. Smythe Jr., James N. Walpole, and Stephen D. Senturia are concerned with the interrelation between the electronic properties of semiconductors and device performance and design.

In a continuing study of defects in electronic materials, it has been found that cooling rate is not a fundamental factor in cooperative diffusion effects between boron and phosphorus in silicon. An investigation of gallium and arsenic diffusion in germanium has been started. Calculations of the strain expected under oxide layer edges in silicon wafers have been made and the true effect of this strain on the electronic band has been determined experimentally. Contrast effects seen in X-ray

topographs of silicon have been analyzed by a "deformed Darwin model" of the strained crystal.

Work on electron absorption in  $\text{SnTiO}_3$  has been completed; a band gap of 3.33-3.34 eV was found at 100°K with at least one band extremum at a  $\Gamma$  or X point in the Brillouin zone. Also completed is a study of temperature modulation of optical absorption in p-type GaAs which suggests multiphonon absorption-edge broadening at room temperature and above, but Redfield's predicted broadening, by the internal electric fields of impurities, at low temperatures. Studies of absorption by trapping defects in CdS and ZnSe are near completion.

The nuclear magnetic resonance program has made good progress in determining and explaining the Knight shift of the  $\text{Pb}^{207}$  and  $\text{Te}^{125}$  resonances in p- and n-type PbTe over a wide temperature range. This work has led to some novel instrumentation developments in the field of NMR (nuclear magnetic resonance) spectrometry. Knight shift in (Pb,Sn)Te and (PbSn) Se is also being studied. In addition, the techniques of NMR are being applied to the study of amorphous semiconductors; the  $\text{Te}^{125}$  resonance in an amorphous chalcogenide has been observed to change significantly at the insulator-to-metal transition in a way which identifies the transition as a thermally induced bulk structural change. Similar studies of transitions have been started in the ferroelectric system  $\text{Na}_x\text{K}_{1-x}\text{TaO}_3$  using the  $\text{Na}^{23}$  resonance.

In the area of device performance and capability, a new theory has been developed for the characteristics of a junction field-effect transistor operating above pinch-off. The question of achieving large values of the number of logic operations per unit time and volume has led to a theoretical investigation of bounds for the maximum packing density of bipolar transistor circuits.

An investigation has been made of the design and fabrication of a high-power transistor as an integrated array of low-power units. This system has built-in negative thermal feedback to counteract the second breakdown phenomenon that imposes basic limitations on conventional bipolar high-power transistors. A major part of this effort is the modeling of the thermal feedback for computer simulation. In another direction, analyses of the internal electronics of high-voltage transistors in the saturation mode have been made, and ways of increasing the high-voltage capabilities of transistors have been explored.

Following the "Great Electric Car Race" of last summer, between students from M.I.T. and the California Institute of Technology, research work has continued on high-power solid-state electronics, rapid battery-charging methods, and electronic propulsion. Further, engineering development of an experimental high-frequency motor with elec-

tronic commutation and speed control has been carried out and development of a linear synchronous motor has been pursued for possible dual-mode transportation or high-speed train applications.

Professor Rediker and his students continue to be heavily involved in materials and device work centered on the lead salts and III-V compounds. In a program to study the physical parameters related to the performance of devices fabricated from PbSe, the lifetime of minority carriers is being examined as a function of material parameters and temperature by observing the luminescence rise and fall times. In an investigation of high-field conduction processes, saturation of the carrier drift velocity has been seen in PbSe and is being studied in detail. A program has been initiated to use radio-tracer techniques to study diffusion in PbSe and correlate the results of this study with our theory and measurements on the motion of p-n junctions in Pb salts. To understand luminescence and laser action in semiconductors further, the luminescence from semiconductors has been modulated with an electric field. Work is under way to understand the electrical and electro-optical properties of GaAs-Ga<sub>x</sub>Al<sub>1-x</sub>As heterojunctions, which have enhanced laser action. In a program to develop a semiconductor suitable for components, that would operate at temperatures up to 500°C, we have grown single crystal SnO<sub>2</sub> of higher purity and higher Hall mobility than has heretofore been reported.

In the materials theory group, Professor George W. Pratt and his colleagues have been investigating the electronic band structure of solids. A new model for vacancy states in PbTe has established that states associated with Pb or Te vacancies lie well up in the conduction band and that no localized states appear in the valence-conduction band gap. Holes and electrons due to Pb and Te vacancies cannot freeze out even at 0°K, giving PbTe the character of a metal at very low temperature. Previous theoretical studies of the effect of strain on energy bands has led to an experimental program on laser activity in strained semiconductor crystals. The lasing properties of uniaxially strained PbSe have been investigated and a precise identification of the laser modes has been made. The frequency modulation of a GaAs laser by compressional ultrasonic waves at 1 GHz has been achieved with a modulation index in excess of 7.5. New broad-band transducers offer the possibility of extending the modulation frequency to 5 GHz with a 25 per cent bandwidth.

Professor David Adler, who has been carrying out theoretical work on transition-metal oxides and on materials which exhibit a metal-to-insulator transition, has extended his activities to include the study of a class of amorphous semiconductors which have potential application for switching and storage functions. Professor Leonard W. Gruenberg has been



concerned with the theory of superconductivity, and, in particular, with fluctuations that occur at the superconductivity transition temperature.

Professor Mildred S. Dresselhaus and her students have been studying the optical and magneto-optical properties of a number of solids in order to obtain detailed information about the energy band structure and Fermi surface properties of these materials. Recent results on the magnetoreflexion spectrum of graphite in the low quantum limit has led to the identification of the sign of carriers in the Brillouin zone and in new information on the shape of the graphite Fermi surface. This work has not only stimulated a number of new experiments on the electronic properties of graphite but has led to the development of a new theoretical technique for treating magnetic energy levels for coupled energy bands in solids. By working at lower temperatures and under conditions of higher magnetic field homogeneity, large-amplitude de Haas-Shubnikov oscillations have been observed in the optical reflectivity of antimony. Unlike preliminary observations of this effect, the present study provides sufficiently definitive line shapes for a detailed investigation of the physical mechanisms involved in this effect.

#### STUDENT ACTIVITIES

##### STUDENT-FACULTY COMMITTEE

The traditional Stu-Fac steak fries were held each term with large and enthusiastic attendance by students, friends, and faculty. The junior dinners were continued, with Course VI juniors meeting with faculty members from specified research areas over dinner to discuss problems and challenges in the various professional activities of electrical engineers. These dinners are sponsored by the Department and have the dual objective of helping students meet faculty members and of helping students select undergraduate thesis areas.

In response to requests by the Undergraduate Educational Policy Committee, Stu-Fac members took part in the evaluation and the studies for future changes in Program VI-2 and in VI-A, the cooperative course.

Also in preparation for the "Agenda Days" discussions organized in the second term, Stu-Fac Committee members helped with the organization of the Department's discussion groups.

##### ETA KAPPA NU, BETA-THETA CHAPTER

Members of the Eta Kappa Nu Chapter served as guides and organizers for the Institute Open House in May. In cooperation with the Stu-Fac Committee, \$250 of prize money was distributed for the best Course VI student exhibits at Open House.

The fall Initiation Banquet heard Professor Bruce speak on the early

history of the Department. At the spring Banquet, Professor Smullin spoke on some of the social consequences of technology and needs for new technologies.

**MORRIS J. LEVIN AWARDS**

The Morris J. Levin awards for excellent performance through independent work in undergraduate laboratory projects were given to the following undergraduate students: First Prize — Lawrence J. Gessman '70, for his project "Arrhythmia Detector"; Honorable Mentions — Charles H. Karaian '70, for his project "Bode Plotter"; and Paula J. Haughey '70 and Joseph B. Walters Jr. '70, for their joint project "EKG Rate Monitor." A number of these projects were displayed at the Institute's Open House.

**FACULTY**

**RETIREMENT**

Professor Yuk-Wing Lee reached the mandatory age of retirement this year. Professor Lee, who was born in Macao in 1904, received the S.B. degree from M.I.T. in 1927, the S.M. in 1928, and the Sc.D. in 1930. Following his graduation from M.I.T., Professor Lee was employed by the United Research Corporation in Long Island City and the China Electric Company. He was then on the faculty at the National Tsing Hua University in Peking and St. John's University and Ta Tung University in Shanghai. As a doctoral student at M.I.T. Professor Lee studied under the late Norbert Wiener. Their collaboration resumed when Professor Wiener visited China and later when Professor Lee returned to M.I.T. as a Visiting Assistant Professor of Electrical Engineering in 1946. Professor Lee was promoted to Associate Professor in 1948 and to Professor in 1960. He received the honorary degree of Doctor of Applied Science from the Catholic University of Louvain, Belgium. Professor Lee offered the first graduate subject in statistical theory of communication at M.I.T. shortly after his return in 1946. Students who studied this subject with him and who later did doctoral research under his supervision are today at the forefront of the communication field. Professor Lee is known as a teacher and friend by those who are his colleagues and students. The Department is fortunate that he has decided to continue his departmental activities next year as Senior Lecturer and Professor Emeritus.

**LEAVES OF ABSENCE**

Professor Amar G. Bose was on sabbatical leave during both terms of the academic year. While continuing to supervise his thesis students, he spent the majority of his time at the Bose Corporation, conducting research in nonlinear systems.

Professor Leonard A. Gould spent both terms of his sabbatical leave at the Michelsen Institute in Bergen, Norway, presenting a lecture series on modern control theory and participating in existing Norwegian research projects. He also continued his own research in the area of control of distributed systems.

Professor Truman S. Gray took his sabbatical during the second term, dividing his time between consulting, visiting other universities, and writing notes for his subjects.

Professor David C. White spent his second year at Birla Institute of Technology and Science, Pilani, Rajasthan, India, as senior American advisor of the Birla-M.I.T. Faculty Exchange Program.

During the two terms of his sabbatical leave, Professor Abraham Bers spent a major part of his time at the University of Paris in research on plasma effects in solids and gases, and writing a book which will be used as the text for 6.58, Electrodynamics of Waves, Media, and Interactions.

During the second term, Professor Bruce D. Wedlock was on leave at the Technical University of Berlin. There he taught a subject in the solid-state area.

Professor Robert R. Fenichel spent the spring term as a visiting senior fellow at the University Mathematical Laboratory of the University of Cambridge, England.

Professor William B. Lenoir spent the year in training at the NASA Manned Spacecraft Center in Houston as a scientist-astronaut.

Lincoln Laboratory was host to Professor Alan V. Oppenheim for the second year as he continued his research in digital signal processing and homomorphic filtering.

Professor David H. Staelin spent the year on leave at the National Radio Astronomy Observatory at Greenbank, West Virginia.

#### NEW MEMBERS OF THE FACULTY

Dr. Mildred S. Dresselhaus joined the faculty as Professor of Electrical Engineering after spending the previous year as Abby Rockefeller Mauzé Professor in the Department. She represents the physics-oriented approach to solid state and as such complements the work of our other faculty in the solid-state area.

Dr. Lawrence S. Frishkopf, whose interests are neurophysiology, electrophysiology, and electron microscopy, joined the faculty this year as Professor of Electrical Engineering. Professor Frishkopf comes to M.I.T. from Bell Telephone Laboratories in Murray Hill, New Jersey, where he was supervisor of the neurophysiology group.

Dr. Julius L. Goldstein, who was a postdoctoral fellow at the Harvard

Laboratory of Psychophysics, was appointed Assistant Professor in the Department this year. Professor Goldstein's field of interest is psychological acoustics.

Keith I. Thomassen, who was a research physicist at Stanford University and also a lecturer at the University of Santa Clara, was appointed Assistant Professor in the Department. Professor Thomassen's field of interest is plasma physics.

Appointed assistant professors after receiving doctorates from M.I.T. were Dr. Jonathan Allen, digital signal processing; Dr. Arthur B. Baggeroer, communication theory; Dr. Dennis D. Buss, experimental solid-state physics; Dr. Thomas G. Davis, ferroelectrics; Dr. John J. Guinan Jr., neural encoding and processing of information (particularly in the auditory system); Dr. Adolfo Guzman Arenas, artificial intelligence; Dr. Fred L. Luconi, computer organization; and Dr. Jan C. Willems, control.

#### RESIGNATIONS

Assistant Professor Arthur L. Anger resigned in order to accept a faculty appointment at Wellesley College.

Associate Professor Roger W. Brockett resigned to join Harvard's Department of Applied Science and Engineering as Professor.

Assistant Professor Dennis D. Buss resigned in order to join an industrial research laboratory.

Associate Professor Leroy L. Chang resigned his appointment in order to accept employment at International Business Machines Corporation.

Assistant Professor Peter G. Katona resigned his appointment in order to accept an appointment as Associate Professor of Electrical Engineering and Associate Professor of Biomedical Engineering at Case Western Reserve University, Cleveland, Ohio. The appointment is a joint appointment with the Engineering and Medical Schools of the University.

Assistant Professor Dennis H. Klatt resigned to accept an appointment as a Research Associate in the Department.

Assistant Professor Michael L. Wiederhold resigned his appointment in order to accept an appointment as Visiting Scientist at the National Institute of Neurological Diseases and Stroke. There he will do intracellular neurophysiological research dealing with visual receptor-cell mechanisms.

Assistant Professor Robert D. Yates resigned his post to accept an appointment at the Lincoln Laboratory.

#### VISITING FACULTY

During the past year the Department once again had a large number of visiting faculty.

Professor Taylor L. Booth, Associate Professor of Electrical Engineering at the University of Connecticut and Director of the Man-Computer Communications Research Project there, pursued his research interests in probabilistic automata and observed the operation and development of the Department's Computer Science Program as Visiting Associate Professor of Electrical Engineering. His host was Professor Zvi Kohavi.

Dr. Chao Kong Chow, a research staff member at the IBM Thomas Watson Research Center in Yorktown Heights, New York, spent the academic year as Visiting Professor of Electrical Engineering working with Professor Minsky in Project MAC on problems of artificial intelligence.

Professor Richard W. Conway, Professor of Computer Science at Cornell University and Director of the Office of Computer Services also at Cornell, spent the first term visiting Professor Dennis at Project MAC, studying the concepts of machine organization. His appointment at M.I.T. was Visiting Professor of Electrical Engineering.

Dr. Edsger W. Dijkstra, Professor of Mathematics at the Technological University, Eindhoven, The Netherlands, spent the period March 1, 1969, to April 15, 1969, at Project MAC presenting a series of lectures, "Structured Programming," and working with Professor Jack B. Dennis in the MULTICS group. He held an appointment as Visiting Professor of Electrical Engineering during his visit.

Dr. Edward Fredkin, Vice President for Advanced Development at Information International, Inc., spent the year as a Visiting Professor of Electrical Engineering working with Professor Minsky's artificial intelligence group and during the second term he taught two sections of 6.47, Introduction to Automatic Computation. Dr. Fredkin will also be at M.I.T. during the coming year.

Dr. Wolfgang K. Giloi of the Technical University of Berlin spent the first term of the academic year as Visiting Professor of Electrical Engineering as a guest of John E. Ward and the Electronic Systems Laboratory's display systems group.

Dr. Richard W. Henry, Associate Professor of Physics at Union College in Schenectady, New York, spent his second year as Visiting Associate Professor while he taught 6.05, Circuits, Signals and Systems, and performed research in the communications biophysics group of the Research Laboratory of Electronics.

Dr. Lev Grigoryevitch Lysenko, Assistant Professor at Kharkov Institute of Radio Electronics, Kharkov, U.S.S.R., worked with Professor Crawford in the Particle Optics Laboratory as Visiting Engineer from March 1, 1969, to June 1, 1969.

Dr. Hosakere N. Mahabala, Assistant Professor at the India Institute

of Technology at Kanpur, taught a recitation section of 6.47, Introduction to Automatic Computation, and assisted in the development of 6.233, Information Systems, during his one-year appointment as Visiting Assistant Professor of Electrical Engineering.

Dr. Rolf Nevald, a visitor from the Technical University of Denmark, taught Electromagnetic Fields and Energy, 6.03, and 6.643, Special Topics in the Solid State and Its Application, during the two terms of the academic year. His appointment as Visiting Assistant Professor of Electrical Engineering was in the Center for Materials Science and Engineering with Professors Epstein and Morgenthaler his hosts.

Dr. Elliott I. Organick, Professor of Computer Science and Head of the Department at the University of Houston, spent the year as Visiting Professor of Electrical Engineering while he assisted in the development of subjects in computer science and continued the research he has been conducting in Project MAC as a consultant since 1966.

Dr. William K. Pratt, Assistant Professor of Electrical Engineering and Director of the Video Systems and Optical Systems Laboratories at the University of Southern California, worked with Professor Huang in the cognitive information processing group of the Research Laboratory of Electronics during his second-term appointment as Visiting Assistant Professor of Electrical Engineering.

Dr. Kalluri Ramalingasarma, Assistant Professor in the Department of Electrical Engineering at the Indian Institute of Technology in Kanpur, was Visiting Assistant Professor of Electrical Engineering during the first term, participating in the teaching activities of the undergraduate electrical engineering laboratory subjects and the research activities of the cognitive information processing group of the Research Laboratory of Electronics.

#### FACULTY AND STAFF AWARDS

Professor Harold E. Edgerton received the John Oliver LaGorce Gold Medal from the National Geographic Society in December, 1968, for his contributions to science and exploration through invention and development of electronic, photographic, and geophysical equipment. He was also the recipient of the Doctor of Laws degree from Doane College in Crete, Nebraska, on May 26, 1969, and the Doctor of Laws degree from the University of South Carolina on May 31, 1969.

Professor J. C. R. Licklizer was elected to membership in the National Academy of Sciences.

Professor Robert H. Rediker was named a Fellow of the American Physical Society and is the 1969 recipient of the I.E.E.E.'s David Sarnoff

Award for his contributions to semiconductor research and injection lasers.

Professor Henry J. Zimmermann was named a Fellow of the Institute of Electrical and Electronics Engineers for his contributions as an educator and director of research and graduate training in the broad field of electronics.

Professor Michael Athans received the American Society for Engineering Education's First Annual Frederick Emmons Terman Award in June, 1969. This award is presented each year to an outstanding young electrical engineering educator, who must be the principal author of an electrical engineering textbook published before June 1 of the year in which his 36th birthday occurs. The book must be outstanding in its contribution to the field, and the recipient must also have shown evidence of outstanding achievements in teaching, research, and other related activities.

Professor Richard N. Spann was named to the Organization of American States' Review Committee of Computer Science in South and Central America.

Professor John J. Donovan was presented the first David T. Schultz Award for Excellence in Teaching in Electrical Engineering for his inspiring and effective teaching in 6.251, Digital Computer Programming Systems. The David T. Schultz award was established early in 1969 through a gift of Baird-Atomic, Inc. establishing the Baird-Atomic Fund. The income from this fund finances the award, which honors the chairman of the executive committee of Baird-Atomic.

The Department presented two Carlton E. Tucker Awards for Excellence in Teaching. The Tucker awards were established in 1962 to honor those who have demonstrated an interest and proficiency in the field of teaching and to help defray the expenses of graduate study. These awards were received by Stuart E. Madnick of the Sloan School of Management, who was recognized for his teaching of 6.251, Digital Computer Programming Systems, and Dr. Rolf Nevald, Visiting Assistant Professor of Electrical Engineering, who was recognized for his teaching of 6.03, Electromagnetic Fields and Energy.

The Supervised Investors Services, Inc. Awards, presented to graduate students who are members of the teaching staff of the Department, went this year to Louis B. D. Braidia, for his teaching of subjects in the area of communications biophysics, where he gave eagerly of his time to teach and assist students; to Frederick A. Centanni, for his teaching of 6.02, Electronic Devices and Circuits, and 6.06, Fields, Forces and Motion, where he expressed true concern for his students; to John R. Coffman, for his outstanding work in the organization and teaching of 6.47, Introduction to Automatic Computation; to Paul Demko Jr., for his conspicu-

ously effective teaching of 6.712, Bioelectronics Project Laboratory; and to Alan B. Hayes, for his teaching of 6.711, Digital Systems Project Laboratory, where whenever a student or fellow teaching assistant had a problem concerning the laboratory, Mr. Hayes made it his problem.

LOUIS D. SMULLIN

### **DEPARTMENT OF MECHANICAL ENGINEERING**

For many years the full professors of the Department have made up the membership of the Senior Council, the principal policy group of the Department. The Senior Council has served as a forum for exchange of opinion, for advising the Department head, and for reaching decisions on both short-range and long-range questions. Its most important function has concerned long-range policy with respect to planning the future character, scope, and activities of the Department. Much of this is established in practice through decisions regarding new appointments, promotions, and academic tenure, for which the collective wisdom and evaluative judgment of the senior faculty are the most important elements in assuring a faculty of high caliber for the future. In recent times the number of full professors has become so large that the Senior Council has become unwieldy for dealing with all questions effectively and economically. Last year, therefore, a Steering Committee of the Senior Council was formed. Largely as a consequence of the new three-division structure and the increased responsibilities assumed by the divisions, the Steering Committee did prove to be a more efficient agency than the full Senior Council for dealing with many matters. It is our plan to continue the format thus developed, with some meetings during the year of the full Senior Council and some of the Steering Committee alone, depending upon the type of business to be handled. The Steering Committee comprises two faculty members from each division, including the chairmen of each division, with the Department head presiding. During the past year the makeup was as follows:

**Mechanics and Materials**

Professor Stephen H. Crandall (chairman)

Professor Ali S. Argon

**Thermal and Fluid Sciences**

Professor Warren M. Rohsenow (chairman)

Professor James A. Fay

**Systems and Design**

Professor Herbert H. Richardson (chairman)

Professor Robert W. Mann



In my report of last year I noted the substantial reorientation of faculty and student research toward human and social problems in comparison with the heavy engagement of earlier years in those types of sophisticated technological problems generated by the military and space exploration activities of the country. This trend continues with accelerated pace, so that the total of our efforts directly related to transportation, to environmental problems, and to health and medicine now constitutes about half the total research within the Department. The two most rapidly growing segments are those concerned with the environment and with medicine.

In the former category are strong and growing activities related to the dispersion of atmospheric pollutants from stacks and ground sources, the formation of pollutants in internal combustion engines, the collection and disposal of the solid wastes and trash of cities, the desalination of water, the containment and collection of large oil spills in off-shore waters, and aircraft noise. Despite very strong faculty and student interest, entry into these fields has posed very difficult problems of financial support. For military and space research, the moneys available are large and relatively easy to obtain, and the Federal funding agencies have a long experience with, and understanding of, the administration of university research. For environmental problems, the moneys available are small and very hard to obtain, and the funding agencies are relatively inexperienced with university research methods and policy. At the present time neither the Federal agencies nor the industrial firms appear to consider university research as an important long-range element in solving and abating environmental problems. We believe that, for the national interest, Federal funding must be vastly increased. Furthermore, Federal agencies should recognize the important long-range role of universities for the solution of environmental problems; the type and quality of research characteristic of the academic environment will lead to results not otherwise possible, and the universities have a disinterested position relative to the regulatory relationship between Federal control agencies and the industrial entities whose pollution potentials are to be controlled. What research has been accomplished thus far, in the face of discouraging circumstances, has required arduous efforts and sacrifice by our faculty, together with a large measure of moral support and internal funding from the M.I.T. administration.

One-fourth of our faculty now engage to some degree in medical research, and the fraction of our total research efforts directed toward medical problems is increasing rapidly. We can now foresee also a rather substantial formal educational effort in biomedical engineering: two new subjects are being developed for presentation in 1969-70. We have developed a close association with the Clinical Research Center at M.I.T.,

and members of our faculty are active in the joint M.I.T.-Harvard discussions concerned with medical and bioengineering education. The breadth of medical interests of our faculty is impressively demonstrated merely by listing the research topics on which they are active: intra-uterine contraceptive devices; corrosion and fatigue of metallic prostheses; properties of natural and synthetic collagen-like material; preservation of biological tissues at cryogenic temperatures; ureteral function; peristaltic blood pumps; intra-aortic balloon pumping for left-ventricle assistance; fluid mechanics of arteriosclerosis; electromyographically controlled artificial limbs; mechanics of the hip joint; friction and wear in animal joints; development of membrane-type blood oxygenators; effects of ultrasonic radiation on the nervous system; development of focused ultrasound for placement of deep but trackless lesions; medical telediagnosis; mobility devices for the blind; rapid braille systems; supervisory remote manipulation. As with environmental problems, the funding situation is difficult, and the moneys available are far from matching faculty and student requirements. This is in large measure owing to the fact that the national medical community, which exerts control over health and medical research expenditures, does not yet fully accept and understand the important role that engineering is to play in medicine.

**UNDERGRADUATE PROGRAM**

**REGISTRATION**

Again this year, as it has for the past several years, our undergraduate enrollment remained approximately constant, as shown by the figures following:

	1967-68	1968-69
Sophomore	44	42
Junior	68	59
Senior	60	72
	<u>172</u>	<u>173</u>

**BACHELOR OF SCIENCE DEGREE, UNDESIGNATED (Course II-A)**

Course II-A is the new designation of the Department's flexible program for students working toward the Bachelor of Science degree without specification. This degree program has become increasingly popular, and now accounts for about 20 per cent of the enrollment in the junior and senior years. To provide proper supervision of the curricula of the increased number of students, Professor Ernest Rabinowicz is sharing his duties as advisor with Professors Thomas B. Sheridan and Ain A. Sonin. Several of the students have a curricular theme polarized around

systems analysis, computers, and design, while others are directing major efforts in such diverse directions as management, ocean engineering, urban studies, and biomedical engineering.

#### UNDERGRADUATE SUBJECTS

The standing Curriculum Committee of the Department has been reorganized as the Undergraduate Committee. During the past year it was under the chairmanship of Professor Joseph L. Smith Jr. The change of name of the committee indicates that it is to be concerned with the whole range of undergraduate activities, including curricula, student-faculty relationships, advisory procedures, and evaluative procedures. Two student members were appointed to the Committee. Their contributions were most effective, and the student membership next year will be increased to four.

The honorary fraternity of the Department, Pi Tau Sigma, expanded its yearly statistical evaluation of subjects and instructors with an essay embodying a critique of the Department's required subjects. This was such a remarkably thoughtful and constructive piece of work that it won the author, Robert G. McGregor, a Compton Prize. The critique was sent by the Department to all the undergraduates and faculty of the Department, and to the Visiting Committee.

Professor Thomas J. Lardner is attempting to adapt the STRESS computer program for use in Mechanics of Solids, 2.01, in order to acquaint beginning students with some of the concepts of advanced structural analysis.

Introduction to Engineering Systems, 2.00, was initiated. It will continue this summer in conjunction with the curriculum development effort of the systems and design division directed toward innovation, design, and experimental engineering.

Professors Henry M. Paynter and Ronald C. Rosenberg continued development of their popular elective subject, Computer Models of Physical and Engineering Systems, 2.101. Next year this subject will be paralleled with a new elementary programming subject currently being developed by Professors Paynter and Douglas P. Adams so that students with no prior programming experience can attend certain common lectures. The new subject, Elementary Programming and Machine Computation, 2.10T, will make available a problem-oriented beginning subject to help satisfy the great demand at M.I.T. for early undergraduate experience with computer programming and applications.

Professor Richardson initiated development of a revised version of the undergraduate core subject, Introduction to System Dynamics, 2.02, to be given for the first time in the fall of 1969. The use of the energy-based

bond graph language is expected to increase markedly the scope of this sophomore subject, particularly in the areas of active and mixed-media systems.

Professor David N. Wormley completed the design and development of AESOPS I, the Analog Experimental Simulator and Operational Synthesizer, which provides a small-scale capability for analog simulation, implementation of instrumentation and control systems, and controlled experimentation. Six of these systems were built at a parts cost of only \$600 each and were class-tested in the laboratory part of 2.02 this year. These electronic simulators will be used in several undergraduate subjects dealing with computation, dynamics, instrumentation, and control.

In response to the growing concern at M.I.T. with the role of technology in our society, Professor Sheridan is developing a new subject, Technology and Social Choice, 21.963, to be taught next year as the second half of a two-term Department of Humanities sequence in technology and society.

Professor Deane Lent wrote a series of monographs to serve as concise text and reference material for Engineering Design and Manufacture, 2.861.

Professor Igor Paul taught the interdisciplinary laboratory subject, Design and Experiment, 2.67, in Professor David G. Wilson's absence. The subject was symbiotically coordinated with Professor Paul's junior-level design subject, Engineering Design, 2.731. The theme was the design of an integrated transportation system for the new city of Columbia, Maryland. This was an exciting project both to the undergraduates and to the industrial representatives who lectured and attended the final presentations.

Under the direction of Professor Richardson a study of the undergraduate core program in design and laboratory was initiated in the systems and design division. Of particular concern are the stimulation of the innovative and creative faculties, competence in graphical and visual expression, methods for computer-aided synthesis, and the development of professional awareness and social responsibility. This effort is expected to lead to major curricular revisions during the next three years.

Professors J. L. Smith Jr. and Ernest G. Cravalho are developing the class notes and problems sets for Thermodynamics, 2.403, for publication as a textbook.

Applied Thermodynamics, 2.60, was developed by Professors Wilson and Joseph Gerstmann to place more emphasis on heat transfer because of changes in the prerequisite thermodynamics subjects. A theme project this year was that of providing cooling for mass-transit subways by methods which cope with the serious problem of heat rejection to already

hot tunnels. Presentations of various student proposals were well received by representatives of subway operators and manufacturers from San Francisco, New York, and Boston. Professor Leon R. Glicksman is considering a revision of this subject to permit expanded coverage of the thermodynamics of gas mixtures and chemical equilibrium important in connection with many current engineering problems.

In an effort to expand the undergraduate thermodynamics curriculum, Professors Cravalho and John P. Appleton undertook the development of a new undergraduate elective, An Introduction to Molecular Thermodynamics, to be offered in the fall of 1969. The objective is to present the fundamentals of the molecular basis of equilibrium thermodynamics and transport processes. In addition, Professor John B. Heywood is preparing to reintroduce an undergraduate elective in the field of power and propulsion to be offered in the spring of 1970.

The Mechanical Behavior of Materials Laboratory continued to put considerable emphasis on teaching by means of specific case studies. The problem considered this year was the design of fuel elements for fast breeder reactors. This problem served to tie together the students' experiences in heat transfer, design, and mechanical behavior of materials.

The Experimental Stress Analysis Laboratory served as a center for the development of demonstration models to illustrate principles in mechanics and elasticity for both undergraduate and graduate subjects.

#### UNDERGRADUATE SEMINARS

The Department offered the following undergraduate seminars:

Douglas P. Adams — The Birth and Care of a City; Modern Marvelous Mechanical Motions

William R. Ferrell — Human Decision Making in Vehicle Guidance

Frank A. McClintock — Problem Solving and Creativity

Henry M. Paynter — The Size and Shape of the Universe

Augustus R. Rogowski — Engineering and Research in Piston Engines

#### ENGINEERING PROJECTS LABORATORY

The Engineering Projects Laboratory continued its operation through the year with Professor Paul as chairman and Woodie C. Flowers as laboratory coordinator. The voluntary faculty membership in the Laboratory, the overall Laboratory space, and the budget remained virtually unchanged from the previous year.

A portion of the Laboratory was specifically set aside for projects related to bio-engineering, and this space became the laboratory for "Engineering in Living Systems." Active projects in this area include de-

velopment of an instrumented hip joint replacement, work related to the "Boston Arm" (an electromyographically controlled elbow prosthesis), and wear and friction measurements in animal and human joints.

The availability of general-purpose instrumentation for Laboratory use was considerably enhanced by the purchase of approximately \$25,000 worth of new electronic and mechanical instrumentation as part of an NSF (National Science Foundation)-M.I.T. cost-sharing grant for instructional scientific equipment. This grant for a total of \$58,259 has now been exhausted.

Efficient use of the excellent instrumentation now available to the Engineering Projects Laboratory will be improved by a computerized inventory and availability listing service expected to be instituted during the coming year.

## **GRADUATE PROGRAM**

### **ENROLLMENT**

In September, 1968, 226 graduate students were enrolled in the Department of Mechanical Engineering as full-time students. In addition, there were 20 Special Students who worked full-time and took only one subject in the Department. Of the regular students, about 127 held Institute appointments as instructors, teaching assistants, or research assistants. Sixty-six received fellowships or industrial support and five were U.S. military students.

Of the students who enrolled in September, about 24 per cent were citizens of foreign countries: 28 from Asia, 9 from Canada and England, and the remainder from South America, Europe, and the Near East.

About 65 of the enrolled students received their undergraduate degrees from M.I.T. Forty-five students had degrees from foreign universities. The remaining students had degrees from the following universities in the United States: General Motors Institute (9); Rensselaer Polytechnic Institute (5); University of California at Berkeley, City College of New York, Drexel Institute of Technology, University of Illinois, Iowa State College, Lehigh University, Northeastern University, Stanford University, and Worcester Polytechnic Institute (4 each); Case Western Reserve, Columbia University, University of Michigan, University of Minnesota, Purdue University, Stevens Institute of Technology, Tufts University, and Virginia Polytechnic Institute (3 each); Auburn University, University of California at Davis, Carnegie-Mellon University, Cornell University, Louisiana Polytechnic Institute, University of Maine, University of Maryland, Michigan State College, University of New Hampshire, Princeton University, and the U.S. Naval Academy; and other universities included Brown, Dartmouth, Johns Hopkins, and Notre Dame.

DEGREES AWARDED

In February, 1969, the Department awarded seven Doctor of Philosophy and eight Doctor of Science degrees, five Mechanical Engineer degrees and 33 Master of Science degrees.

As of February, 1969, 216 graduate students were registered in the Department. Of these, eight received Ph.D. degrees, 11 received Sc.D. degrees, eight received Mechanical Engineer degrees, and 37 received Master of Science degrees in June, 1969. Of the graduate students remaining, 63 have passed the qualifying examination and are working, or will start, on their doctoral programs.

In September, approximately 30 students should receive their Master of Science degrees in mechanical engineering. Since the Department does not allow doctoral thesis presentations in the summer term, doctoral students completing their degree work in the summer will officially graduate in February, 1970.

FORECAST FOR SEPTEMBER, 1969

Estimates of actual enrollment in September of 1969 are extremely difficult to make in light of the feelings of graduate students with regard to the Selective Service, as well as to the unpredictable but real possibilities of significant reductions in government funds available for research. We had feared that these same two factors would seriously affect our graduate enrollment in 1968-69 and were relieved that the effect was smaller than anticipated. There is reason to believe, however, that the adverse effects will be much stronger in 1969-70, particularly with regard to the numbers of doctoral students.

SUBJECTS

Professors Lardner, Charles A. Berg, and William J. Shack completed the design of a new sequence of graduate subjects in solid mechanics, consisting of Introduction to Mechanics of Continuous Media, 2.072; Plasticity and Anelastic Deformation, 2.073; and Elasticity, 2.074. The first two were given this year by Professors Berg and Lardner and the third will be given by Professor Shack next year.

Professor Crandall introduced additional student use of the IBM 1130 computer into Methods of Engineering Analysis, 2.092.

Professor Lardner revised Advanced Mechanics, 2.083, to make it more relevant to present-day engineering applications with emphasis on the concepts of elasticity and on the analytical, numerical, and experimental methods needed to solve problems.

A major restructuring of the graduate core subjects in system dynamics and control is under way as a result of a study of this area completed last

year by Professors Dean C. Karnopp, William R. Ferrell, Wormley, Richardson, and Visiting Professor Chi-Neng Shen. The new recommended introductory Advanced System Dynamics and Control, 2.151T, was given for the first time in the fall and was enthusiastically received by the students. It covers physical system modeling, energy functions and optimization, state-space methods and automatic control, and design applications. A follow-on subject, Modern Control Theory and Applications, 2.152, was also given for the first time this spring.

Professor Forbes T. Brown, in collaboration with Professor Daniel E. Whitney, further developed Modeling and Simulation of Dynamic Systems, 2.141T. Text material was produced in the areas of computer simulation and system modeling. This subject provides an advanced view of modeling and simulation and is intended to follow and complement Advanced System Dynamics and Control, 2.151T, which emphasizes the dynamics and control aspects of engineering systems. Professor Brown also prepared new class notes for his subject, Distributed Systems, 2.153.

Professor Shih-Ying Lee, with Professor Wormley, continued extensive revision and improvement of Fluid Power Controls and Fluidics, 2.171. Emphasis was placed on basic understanding of analytical techniques and design procedures for fluid control systems. Many new and interesting fluidic components were used as examples in lecture and laboratory. The laboratory part of the subject was revised and provides an unusual opportunity for graduate students to deal with the analysis and experimental evaluation of real physical systems. Professor Lee also made numerous changes in Instruments for Measurement and Control, 2.173, which deals with instrumentation principles, energy and signal transduction devices, and large instrumentation systems.

In line with the program of new subject development in dynamics and control, Professor Paynter explored in a staff-graduate seminar the area of electromechanical engineering defined as the union (rather than intersection) of the core disciplines of electrical and mechanical engineering. As one outcome, two new subjects are being developed by Professor Paynter to be taught beginning next year: Control of Rotating Machine Systems, 2.154T, and Analog/Digital Computation for Instrumentation and Control, 2.161T. The latter subject will draw heavily on the new hybrid computer facilities currently being developed in our Department and will be taught jointly by Professor Paynter and Richard S. Sidell.

Professor Dwight M. B. Baumann represented our Department in the interdisciplinary subject, Special Studies in Systems Engineering, 2.191T. He participated in two topics: the first involved a small group (together with Professor Paul) which designed a horizontal-vertical elevator system for transportation in dense urban areas, and the second (in conjunc-



tion with several faculty from other departments) dealt with a system of transporting oil from Alaska. The students in the latter project compared ice breaker tanker and submarine tanker options to a trans-Alaska and trans-Canada pipeline. Approximately 80 visiting professionals attended the formal final presentations by this student group.

A new subject at the senior-graduate level to be offered next year will introduce students interested in bio-engineering to research activities currently under way in the Department. Special Topics in Biomedical Engineering, 2.74T, was organized by Professors Mann, C. Forbes Dewey Jr., Ioannis V. Yannas, and Padmakar P. Lele. Lecture material with appropriate laboratory demonstrations will stress the engineering contributions and present relevant biological and medical information on topics such as neurosensory control and feedback for prostheses, the fluid mechanics of cardiac assists, ultrasonic neurosurgery, and collagen as a biomaterial.

Michael S. Baram continued the development of Legal Aspects of New Technology, 2.96J. Within the context of the interrelationship of technology, society and the law, a new series of case studies was presented. Topics included: technology and the consumer — the impact of Ralph Nader; industrial patent and trade secret practices; the social role and mobility of the engineer; Federal agencies and the transfer of technology; and computer technology and the emergence of societal and legal issues.

The subject, Dynamic Fluid Machines, 2.275, was revised and taught by Professor Wilson on a design-problem-solving basis rather than one emphasizing fluid-mechanical-analytical techniques. As part of the teaching and assignments, current turbomachinery problems, ranging from man-powered irrigation pumps to aircraft-escape systems, were designed. A turbine-driven fan was built largely following the design recommendations arrived at during the subject, and, on test, substantially exceeded all design objectives (after two initial models had burst). This machine seems likely to be adopted by the industry.

Professor Brandon G. Rightmire is developing a new set of notes for Theory of Material Interface Phenomena, 2.865. In response to students who had taken Engineering Design and Manufacture, 2.861, Professor Pangal N. Nayak offered a revised version of Research in the Mechanical Processing of Materials, 2.869, with a small number of lectures in addition to research work. A special feature in Applications of Material Interface Phenomena, 2.866, was a special series of lectures on Applied Electrochemistry by Dr. Jean-Marie Georges.

A major revision of Advanced Thermodynamics, 2.452, involving the introduction of a new formulation of quantum statistical thermodynamics, was undertaken by Dr. George N. Hatsopoulos in collaboration with Professor Joseph H. Keenan and Professor Elias P. Gyftopoulos of the

Department of Nuclear Engineering. In addition to integrating the concepts of quantum mechanics into classical thermodynamics, this formulation holds promise of resolving much of the confusion concerning the nature of irreversibility and entropy in nonequilibrium systems.

Professor Cravalho, with Professor Glicksman, presented for the first time Radiation Heat Transfer, 2.58, which stresses the physical mechanisms underlying radiative processes and the manner in which these mechanisms influence the performance of engineering systems.

Professors David P. Hoult, Fay, and Heywood offered the new subject, Fluid Mechanics of Pollution, 2.283, with the objective of providing a broad background in environmental problems and with particular stress on the application of engineering methods to predict and control pollutant emission.

The Fluid Mechanics Laboratory organized a new subject, Biomedical Fluid Mechanics, 2.277, to be offered next year to second-year graduate students. The subject, to be taught by Professors Dewey and Michel Y. Jaffrin, will be of interest to students in a wide variety of disciplines who are concerned with human systems.

#### SPECIAL SUMMER PROGRAMS

Once again the Departmental faculty made strong contributions toward the Special Summer Programs of the Summer Session. The following programs are planned for the summer of 1969: Recent Developments in Mechanical Vibrations, by Professors Jacob P. Den Hartog and Allan D. Pierce; Strain Gage Techniques — Lectures, Strain Gage Techniques — Laboratory, and Non-Destructive Testing, all three given by a staff drawn from universities and industry under the direction of Professor William M. Murray; Physical Measurement and Analysis, directed by Professors Nathan H. Cook and Rabinowicz; and New Developments in Modeling, Analysis, and Simulation of Engineering Systems, under the direction of Professors Karnopp and Rosenberg.

#### RESEARCH

##### MECHANICS AND MATERIALS DIVISION

**MECHANICS** Professor Crandall and his students continued investigations of structural vibration due to seismic, acoustic and aerodynamic excitation and of random vibrations of complex structures. Studies were completed on the excitation of continuous structures by vibrating foundations and on the general problem of random vibration of interconnected structures. Summary papers on first-passage problems and random vibration of nonlinear systems were prepared for presentation at international meetings.

Dr. Huw G. Davies continued analytical and experimental study of structural-acoustic interaction problems and completed a study of acoustic radiation from vibrating panels excited by turbulent boundary-layer flow.

Professor Lardner completed investigations on variational principles for coupled radiation and heat conduction problems and on mathematical relationships between special functions. Professor Lardner and his students are also studying post-buckling behavior of structures and have begun to investigate the mechanics of intra-uterine devices.

Professor Patrick Leehey of the Department of Naval Architecture and Marine Engineering and his students completed a study of the vibration of thin panels interacting with acoustics fields and boundary-layer flows and continued the investigation of vortex shedding with application to the problem of singing of marine propellers.

Professor Pierce and his students developed a computer program for predicting the far-field waveforms from nuclear explosions and investigated anomalies in sonic-boom waveforms. An explanation based on atmospheric turbulence was proposed and is under further development.

Professor Shack is continuing studies in continuum mechanics on viscoelastic and elastic-plastic media and on mixtures.

**MATERIALS** Professor Berg and his students investigated the physics of damage and fracture in fiber-reinforced materials. They found that interlaminar shear fracture under transverse compression is completely different from that under transverse tension.

Professor Argon continued studies on deformation and fracture. Research on the rate mechanism of plastic deformation concentrated on a detailed experimental and theoretical study of the jerky motion of dislocations in sodium chloride crystals which elucidated the distribution of the slip obstacles and their thermal penetrability. Research on fatigue crack propagation in an iron-silicon alloy showed that the path of a tensile fatigue crack is locally very wavy both in the direction of crack propagation and transverse to it, and requires the solution of the plastic strains at the crack tip in two or three combined modes of deformation. Research on tensile failure of laminates elucidated several important side effects resulting from the mutual interactions during fracture of reinforcing elements.

Professor Frank A. McClintock and his associates worked toward a quantitative understanding of ductile fracture — the most common mode of tensile failure in structural materials under monotonic loading. Results include the solution for growing cracks in shear, the discovery of an instability in flow from which part of the crack growth in fatigue has been pre-

dicted, the computer modeling of plastic flow fields by dislocation arrays, and the plastic stress and strain fields around cracks in fiber-reinforced composites.

Professor Egon Orowan continued to be active not only in his experimental studies on the failure of adhesive joints but also on his theoretical studies on geotectonics and the constitution of the moon and planets. In the first area, a study of cleaved adhesive joints made with epoxy or "Eastman 910" showed that brittle crack propagation in the joint is arrested by a louver-type fragmentation of the crack front, making the overall process of separation very jerky. In the second area, a new model of geotectonics, named "transvection" proposes that rheospheric flow from one region toward the antipodally opposite region occurs: this is compensated by a rigid-body translation of the firm part of the mantle complemented by a centripetal displacement of the core driven by gravity. This model is able to account satisfactorily for various important features of the continents, and the oceanic hemisphere. An additional study concerned with the nucleation of the planets, proposes that cores of planets have nucleated by the welding collisions of metallic particles followed by later gravitational capture of silicate particles. This possibility might account not only for the lower density of the moon but also for a general decrease of the space density of metal particles away from the sun, which may be the basis of the Titius-Bode law.

In their research in the Experimental Stress Analysis Laboratory, Professor Murray and his associates devised a simple and inexpensive electrical network for direct compensation of strain gages. A method has been developed for representing visually on an oscilloscope the Mohr circle for stress under both static and dynamic conditions. In addition, a strain gage device for indicating the distribution of pressure in the human hip joint, and involving a miniaturized radio transmission system for permanent installation in the patient, is under development.

**MATERIALS PROCESSING AND SURFACE LABORATORIES** Professor Rightmire continued work on boundary lubrication at very low speed, where persistence of an adsorbed film of lubricant is determined by thermodynamic stability; a theoretical mechanism of film breakdown was developed which appears to check experimental results. He is working jointly with Professor John Wulff of the Department of Metallurgy and Materials Science on the growth of oxide films on metals at room temperature and slightly above.

Professor Walter D. Syniuta continued studies on the origin of rolling contact fatigue. Several new techniques were developed with the aid of both electron transmission and scanning electron microscopes for the

study of high-strength steels such as bearing materials. Hydrogen embrittlement as well as strain softening are suspected as causes of early failure in rolling elements. Professor Syniuta is continuing a program of research in the field of grinding, in which grinding forces and energies are measured and are related to the development of wear-flat areas.

Professor Nayak continued investigation of the cratering wear mechanism of cemented carbide tools. Reductions in wear rate associated with multcarbide tool compositions were identified as being due to reduced cutting temperatures rather than due to any changes in the wear mechanism. Electron microscope studies indicate that changes in chip-tool contact length, which have a strong influence on cutting temperature, may be due to changes in the fracture characteristics of the chip-tool bond.

Professor Cook continued to explore rate-limiting mechanisms in electrochemical machining. The effect of reverse current pulses in removing anodic films was explored. Electrochemical machining was carried out at current densities as large as 17,000 amps/in<sup>2</sup>. Professor Cook also extended work on the use of an active servo system to stabilize a machine tool. This effort produced increases in cutting capability by a factor of fifteen before chatter ensues.

Professor Rabinowicz continued work on mechanical reliability and interface damping. He initiated a study on oil drop impingement on rotating shafts.

**FIBERS AND POLYMERS** Professor Yannas completed a study of the non-linear viscoelastic behavior of glassy polycarbonate over a very wide range of temperatures. These data are being used to test the applicability of the Volterra treatment, as well as of a new constitutive relation currently under development. Unequivocal evidence of strain-softening, as this occurs during the process of deformation of glassy polymers, was finally documented and is being applied towards a clarification of neck formation and subsequent cold drawing of polymers. Rheological instabilities sometimes give rise to unexpected mechanical effects. Such is the case with quenched-amorphous Mylar film which, when studied within a very narrow range of temperature and load, cold-draws by massive fracturing internally, even though no sign of macroscopic fracture is evident outside.

Dr. Emery I. Valko studied the differential distribution of crosslinks in cotton fibers by application of crosslinkers from solvents. In addition, he investigated the diffusion of dyes in crosslinked cellulosic materials such as cotton, rayon, and cellophane as an example of the influence of crosslinks on the diffusion in polymers in general.

Dr. George B. Damianov devoted the year to a study of weaving dy-

namics. He lectured on looms and weaving technology, using this material as a basis for publishing the first English-language text on this subject.

Professor Stanley Backer, while on sabbatical leave, continued to work with Dr. Valko towards completion of a program on textile information retrieval. The second edition of the *Thesaurus of Textile Terms* was published by the M.I.T. Press in April, 1969. It already has been translated into five languages and is providing a sound basis for international cooperation in information flow between countries in Western Europe. The final tests of the computer retrieval system, incorporating the thesaurus, will be completed at the Institute during the summer of 1969.

#### THERMAL AND FLUID SCIENCES DIVISION

**THERMODYNAMICS** Professors James C. Keck and Heywood, in collaboration with Professors Fay, John P. Appleton, and Augustus R. Rogowski continued research on problems related to air pollution from internal combustion engines. As yet it has not been possible to obtain external funding for this research, which is most surprising in view of the importance of this topic.

Professor Robert E. Stickney and his students concentrated on problems relating to processes occurring at gas-solid interfaces, including adsorption and desorption, permeation, high-temperature oxidation, and the inelastic scattering of atoms from surfaces. Studies of the mechanism of electrical discharge machining were also extended. Complementary theoretical studies of adsorption and desorption are being pursued by Professor Keck, using techniques borrowed from gas phase kinetics.

A five-year project on the formulation of the thermodynamic properties of steam culminated in the publication of two volumes, one in English units and the other in metric units, entitled *Steam Tables* by J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore. These are based on a new achievement, namely, a single fundamental equation covering all vapor and liquid states from the triple point of water to 1,300°C (2,400°F) and from zero pressure to 1,000 bars (15,000 pounds per square inch). Professor Keenan's name has been associated with the properties of steam for some four decades, the new volumes being the third steam tables of which he is principal author.

Professor Appleton and Dr. Thomas I. McLaren initiated shock-tube experiments to study collisional energy transfer in rapidly cooled gases. The purpose of this work is to gain a better understanding of the detailed kinetic mechanisms which are important in many combustion problems and to certain aspects of gas laser operation and re-entry physics.

Professor Gerstmann completed a study of nonevaporative cooling towers for electric power plants. The study puts limits on possible cost

reductions and indicates in which areas further research may be profitable. A reduced-order, nonlinear dynamic model of a supercritical steam generator is being developed which is intended for use in the central computer control of power systems.

**CRYOGENIC LABORATORY** Professors Herbert H. Woodson of the Department of Electrical Engineering and J. L. Smith Jr. continued to study the application of cryogenics to electric power generation. An 85-KVA (kilovolt ampere) synchronous generator with a rotating superconducting field has been built and successfully tested. This is part of a long-range effort by the Edison Electric Institute to apply superconductors to large synchronous machines. In a related field, Professor Cravalho initiated a project to investigate the use of liquefied natural gas as a cryogenic coolant for underground electric power transmission lines.

Professor Smith continued a variety of projects in the field of cryogenics. An experimental Stirling engine was used to verify an improved thermodynamic analysis of the Stirling cycle. The project is now directed toward the development of a hot gas engine in cooperation with Dr. Vannevar Bush. The study of boiling heat transfer to cryogenic liquids focused on boiling under transient conditions. Work on the freeze-out of impurities in a thermal regenerator is nearing completion with the actual measurement of the distribution of the impurities frozen in the regenerator. A new cryogenic refrigeration system employing metal bellows is nearing completion.

The investigation of the distillation process in a  $\text{He}^3\text{-He}^4$  dilution refrigerator continued. Present efforts are focused on the competition between the mass transport due to concentration gradients and that due to temperature gradients in the superfluid  $\text{He}^4$ .

Professor Cravalho continued investigation of the propagation of thermal radiation in highly absorbing media. Preliminary results shed new light on the use of the Stokes principle of reversibility at the interface between a dielectric medium and a metal. A related effort resulted in the construction of an apparatus for experimental measurement of the thermal radiation properties of metals at cryogenic temperatures. Another apparatus was constructed to investigate the influence of freezing and thawing rates on the preservation of biological specimens at cryogenic temperatures.

**HEAT TRANSFER** Professor Rohsenow continued his work on the condensation of liquid metals. An important result of this year's work was the development of an error analysis to show the limits of precision in condensation experiments and thus explain anomalies in previously reported data. He also continued work on the boiling of liquid metals, on

flow-induced vibrations of heat exchanger tubes, and on the influence of nuclear radiation on boiling nucleation.

Professors Rohsenow and Arthur E. Bergles completed an experimental and analytical study of dispersed-flow film boiling. Experimental data for nitrogen and available data for other fluids were correlated by an extension of a semi-empirical model accounting for nonequilibrium thermal conditions. It was demonstrated that heat transfer coefficients can be increased by a factor of two or three by use of full-length twisted tapes inserted in the flow channel.

Professor Bergles completed a study of the mechanism of critical heat flux in subcooled flow boiling. Photographic, electric probe, and thermocouple observations were used to establish the thermal and hydraulic conditions at the critical condition. These observations aided in the formulation of an analytical model. The first phase of an investigation of the boiling heat transfer characteristics of fluorocarbon liquids, used in cooling electronic components, was completed. Experimental studies of internally finned or roughened tubes and tape-generated swirl flow in smooth and rough tubes were continued. Professor Bergles and his students also investigated the stability characteristics of multiple tube boilers. Experimental data from a large Freon loop were used to define precisely the onset of oscillatory behavior. Analyses of the instability threshold and frequency, as well as the limit cycle, were continued.

Professor Borivoje B. Mikic investigated effects of thermocapillary flow on heat transfer in dropwise condensation. Professor Mikic also continued research on the effects of the thermal properties of a condensing surface on heat transfer in dropwise condensation.

Professors Rohsenow, Bergles, and Mikic initiated an investigation of the effects of surface properties on heat transfer in nucleate boiling. Professors Mikic and Glicksman considered a method for augmentation of heat transfer in film condensation outside of a horizontal tube. The method consists of depositing a thin strip of Teflon layer at various positions on the outside surface of the tube.

Professor Glicksman continued work on simultaneous convection and radiation heat transfer in absorbing media. A method of finding the temperature distribution in high-temperature media by measuring the attenuation of a laser beam was successfully demonstrated. An approximate analytical method for calculating the temperature distribution and heat fluxes in an absorbing, emitting medium of arbitrary geometry was developed and shown to give accurate results for all values of the optical thickness. The radiation properties of slag on boiler tubes were investigated; at one temperature, slag was found to exist in crystalline and amorphous structure, corresponding to stable and metastable equilibrium



states respectively, with large differences in absorptivity between the two states. Transitions from the metastable state are responsible for thermal fatigue of boiler tubes.

Professor Glicksman's investigation into the mechanics of glass fibers continues. A low-temperature fluid analogy of the fiber-forming process was developed to study flow instabilities, and effects of two-dimensional velocity distributions in the jet flow were considered analytically.

Professors Peter Griffith, Bergles, and Mikic initiated work on the mixing of two phases in a rod-bundle geometry. This work is of particular interest to manufacturers of nuclear reactors. An investigation into the pressure drop and void in inclined pipes with two phases flowing has also been initiated by Professor Griffith. This work is of interest to the oil industry. Work was completed this year by Professor Griffith on heat transfer to supercritical CO<sub>2</sub>, bubble growth rates at very low pressure and on the naturally occurring momentum fluctuations in a gas-liquid system.

**FLUID MECHANICS** A major effort of the staff of the Fluid Mechanics Laboratory was the solicitation of research support for an expanding program of graduate-level research in air and water pollution. Apart from the fruits of the research, the intent of this program is to prepare graduate students for research, development, and control administration activities concerned with environmental pollution resulting from industrialization.

Despite very great difficulties in obtaining adequate support from government and industry, work is continuing on problems of air and water pollution. Theoretical studies of the aerodynamics of smoke plumes were continued by Professors Fay and Hoult and Dr. Marcel P. Escudier. Two simple formulae, for computing the rise and leveling-off of a buoyant plume in a stratified atmosphere, were recommended as adequate engineering approximations to a more complete theory previously discussed. These formulae were shown to apply well to plumes emanating from stacks of widely different size and source strength.

A stratified-flow wind tunnel, capable of simulating the interactions between a buoyant plume and its environment, was built and is currently in the commissioning phase of development.

Dr. Escudier and Professor Hoult studied, both experimentally and theoretically, the large-scale structure of turbulent shear flows. The novel feature of the experimental study was the use of a high-speed movie camera to record photographically the randomly varying position of the interface between the turbulent flow within a plane jet and its irrotational surroundings.

Professors Fay and Hoult continued research on the spread of oil slicks on the open sea and methods of containing and collecting large-scale oil

spills in the presence of wind, waves and tidal currents. A conference, "Oil on the Sea," jointly sponsored by M.I.T. and Woods Hole Oceanographic Institution, was attended in May by more than 250 engineers and scientists.

With Professor Ronald F. Probstein, Professor Sonin continued research in the desalination of sea water by electro-dialytic methods. Results from their recent theory are being confirmed experimentally, and have been used to indicate an economic optimization of the process. Professor Sonin also continued laboratory experimentation in rarefied plasmadynamics, simulating in a wind tunnel various problems associated with the interaction of a satellite with the earth's ionosphere.

Ideas developed by Professor Probstein in the vacuum-freezing research will be tried out in practice by Colt Industries on a 200,000-gallon per day pilot plant. A third area of research in water desalination recently undertaken is in reverse osmosis, where a possible mechanism for how reverse osmosis membranes operate has been developed. Research in electro-dialysis and reverse osmosis was carried out jointly with Professor Sonin.

Research was also continued by Professors Probstein and Sonin and their students in the areas of explosion phenomena and low-density aerodynamics.

Research on peristaltic pumping was continued this year by Professors Ascher H. Shapiro and Jaffrin and their students, with the principal objective of understanding how the ureter works. The theory of peristaltic pumping is also being applied to the design of roller pumps with the purpose of minimizing blood trauma during pumping.

The engineering development of the intra-aortic balloon technique for assistance of the left ventricle was continued by Professors Shapiro and Jaffrin and Dr. V. Sreedhara Murthy. A general theory for counterpulsation in the arterial system was set up.

A novel method of exciting partially ionized gases with a laser was proposed by Professor Dewey. The related experimental investigation, initiated this year, is being conducted on a cesium plasma whose characteristics resemble a thermionic energy conversion device. Allied research on tunable dye lasers is also being pursued.

Professor Dewey has also initiated research in collaboration with Professor Robert S. Lees of the Clinical Research Center, aimed at a better understanding and clinical observation of the fluid mechanics associated with arteriosclerosis.

**GAS TURBINE, SLOAN AUTOMOTIVE, AND COMBUSTION LABORATORIES** With Professor Wilson, Professor Edward S. Taylor of the Department of

Aeronautics and Astronautics studied the flow in centrifugal impellers. This program yielded a more detailed understanding of the boundary-layer behavior in such rotors, including a technique for estimating separation. Professor Taylor also completed his study on unconventional blading for axial compressors.

Professor Wilson investigated secondary flows in an axial-to-radial diffuser and the turbulent boundary layer over a two-dimensional step.

Professor Rogowski continued an investigation of combustion and flame propagation in premixed charges and the penetration, mixing, and burning of Diesel fuel sprays in swirling air. A specially designed laminar-flow tunnel and a highly modified engine with a transparent cylinder head were used in this work, as well as an improved version of the M.I.T. rapid-compression machine. Much new information was obtained regarding the mechanisms and control of combustion rate and steadiness.

In collaboration with Professor Tau-Yi Toong, Professor Richard F. Salant initiated work on the utilization of optical holography as a flow visualization technique, with emphasis on the detection of acoustic waves. Initial research involved studies of jet noise, while future work will concentrate on noise generated by aircraft fans and compressors. A study of acoustic rays in rotating flows was completed by Professor Salant.

Professor Toong continued research on supersonic combustion and sound propagation in chemically reacting flows. He completed a study of a surface-tension problem which shows the importance of hydrodynamic effects on dynamic contact angle. He also completed an investigation of the electrical control of carbon emission from diffusion flames, which showed that carbon emission can be reduced by more than 90 per cent in the presence of an electric field.

#### SYSTEMS AND DESIGN DIVISION

As in other areas of the Department, research activities in the systems and design division moved increasingly toward problems of a human and societal nature such as transportation, bio-engineering, waste management, safety, engineering for underdeveloped countries, and sensory aids.

Professor Paul continued his experimental work on steady and unsteady slip phenomena in the interface between a metal wheel and rail.

Professors Richardson and Wormley continued research in the dynamics of unconventional suspension systems for high-speed and urban transport vehicles. Significant results were obtained on the optimization of fluid suspensions using active feedback control between cushion pressure and source flow. Improvements of up to 30 times in ride comfort are indicated compared with conventional systems, a fact which appears to permit operation at very high speeds over guideways containing realistic

irregularities. A new project was undertaken this year dealing with the dynamics of flexible guideway structures having nonrigid supports. Of particular interest are techniques for controlling or managing span length and other physical properties as well as support dynamics to minimize unsatisfactory interactions between single or multiple vehicles and the guideway. This work is applicable to high-speed systems and to moderate-speed urban transit or dual-mode configurations.

Professor Wilson pursued his concept of palletized automated transportation (PAT), and one of his students developed a table-top demonstration model as an S.B. thesis. A doctoral candidate continued analytical and experimental studies of the fluid dynamics of the entry of high-speed vehicles into tunnels.

Dual-mode guideway research using modified conventional automobiles continued under Professor Baumann. A 200-foot test track was completed and a prototype automobile was operated under passive steering control referred to a mechanical guidance rail. The rail is electrically powered and will supply an electric motor which will be installed on the back side of the automobile differential so that the gasoline engine can be turned off during operation on the guiderail. An active followertype steering control was also developed and tested. This system combines the flexibility of personal vehicles with the control and channel capacity of an automated transit system to achieve optimum door-to-door convenience.

Professor Sheridan participated in an Urban Systems Laboratory project on methodology for analyzing community impacts of alternative highway locations.

Professor Wilson, assisted by Joan G. Moore, completed a study under the General Motors Highway Safety grant which developed a new method of highway-accident reporting and analysis. It includes a computer program that converts raw data from investigating officers and, with costs and engineering inputs, produces a resource-allocation plot showing where funds should be allocated first to bring about improvements in safety. A Master's student worked on a joint project with the Law-Medicine Institute of Boston University as the engineer member of a team investigating fatal accidents in the Boston area.

Professor Wilson, with the collaboration of Professor Paul, organized and led a summer study group on solid-waste management. The results of this study received national attention. Several cities have informed M.I.T. that substantial savings resulted from following the group's recommendations. In addition, several new research programs funded by the Public Health Service were initiated in the Departments of Mechanical Engineering and Chemical Engineering as a result of the summer activities.

Professor Baumann and his students completed work on the conversion of junked automobiles to tractors in remote areas of underdeveloped countries. Requests for design details came from many parts of the United States and several foreign countries. A student working with Professor Wilson developed and tested a simple windmill for use in underdeveloped areas.

Two students joined Professor Wilson to produce a new design of rowing shell, and subsequently trained a newly formed black business group in the production methods for this shell. All assets of the enterprise were subsequently transferred to the black firm.

Several faculty in the systems and design division were active in various aspects of biomedical engineering, as described below.

Professor Mann's work in applying engineering to the rehabilitation of humans with major sensory and muscular-skeletal deficiencies continued and expanded. The proportional-rate, force-sensing, electromyographically controlled artificial elbow which has resulted from M.I.T.'s collaboration with the Harvard Medical School, the Massachusetts General Hospital (M.G.H.), and the Liberty Mutual Insurance Company was formally presented at a press conference at M.G.H. and dubbed "the Boston Arm." The enthusiastic response of amputees to both short- and long-duration use of the battery-powered limb is being extended to clinical field evaluation at six orthopedic and prosthetic clinics nationally.

Further research at M.I.T. on the limb included a psychophysical study of the contribution to limb performance of a novel means of elbow-position sensory feedback proposed in a doctoral thesis last year. The current thesis, conducted with the cooperation of Professor Richard M. Held of the Department of Psychology, showed that the cutaneous "Phantom position" display provides the EMG (electromyographic) limb with proprioceptive feedback equivalent to that possible with conventional cable-operated artificial elbows.

Design studies were undertaken to enhance the "Boston" elbow with wrist rotation and hand prehension. Professor Whitney, working with Professor Mann, extended his research on remote manipulators to include the coordinated control of a multiple-degree-of-freedom limb. An analysis has been made of a model of the nerve signal transmission mechanism, the results of which correlate with available experimental observations.

Mr. Flowers is defining a doctoral investigation, under Professor Mann, of an adaptive knee mechanism for leg amputees which would derive its control information from the bioelectrical activity in the stump of the amputee.

A related biomechanical study is concerned with the spatial and temporal pressure distribution across the human hip joint. With collabora-

tion from Dr. William B. Harris at M.G.H., a doctoral student under Professor Mann designed and tested a physiologically acceptable pressure transducer implanted, at 20 discrete locations, into an otherwise standard femoral head replacement prosthesis. This study will contribute to the elucidation of the mechanism of joint lubrication and bone deterioration and supports Professor Paul's direct studies of animal joint friction and wear.

Dr. Philip A. Drinker and Professor Richard A. Moss continued the analysis and development of the toroidal flow membrane oxygenator system initiated last year. Animal experiments demonstrated that partial respiratory support (extracorporeal) is feasible for up to five days with this blood oxygenator. Encouraging progress was made on the fluid mechanics and mass transfer analysis which will lead to optimal system design and operation.

Professor Lele continued research on the effects of ultrasonic radiation on the nervous system and development of focused ultrasound for placement of deep but trackless focal lesions. This work is being extended to the production and detection of myocardial infarcts.

Professor Sheridan initiated new research, under support from the National Institutes of Health and in cooperation with the M.I.T. Instrumentation Laboratory and the Massachusetts General Hospital, on medical telediagnosis, whereby a physician at one location can diagnose a patient at a remote location, using high-bandwidth TV, audio, and bilateral electromechanical control devices.

Professor Mann's research on sensory substitutes for the blind was concentrated this year on the problem of mobility. The earlier program in the Department, directed toward enhancing the availability of braille, has been largely transferred to the M.I.T. Center for Sensory Aids Evaluation and Development, where the refined version of the high-speed braille embosser is reaching production and where, for the first time, type compositors' tapes were used in conjunction with computer braille translation to produce a simultaneous publication of a new novel in embossed braille as well as in ink print.

Current mobility research is exploring the effectiveness of a tactile output for the "Pathsounder" ultrasonic mobility aid developed at the Center; heretofore the aid prompted the blind traveler audibly. A doctoral student is simulating the applicability of Alles' "Phantom position" phenomenon, used successfully in the "Boston Arm," as a possible means of conveying to the traveler by an inconspicuous, yet spatially congenial means, the trajectories of stationary and moving obstacles relative to the mobile blind person.

Considerable effort went into a detailed study of the feasibility of a

major new computer-based simulation environment with which to evaluate mobility devices, synthesize optimal specifications for new travel tools, and develop a theory of human mobility.

Professor Paynter continued research in the dynamics of rotating machine systems. With Professor Brown, he is exploring the detailed mechanisms that have led to unexpected and repeated severe damage to a large pump-turbine unit. A doctoral student developed a detailed digital simulator for a generalized four-winding electrical machine. This work will be used as a tool for continuing research on control of rotating machines.

Professor Whitney initiated new research in applications of dynamic programming to optimize machine tool cutting strategies and continued his work on computer control schemes for artificial limbs and manipulators.

The Department's long-standing basic research effort in fluid power systems and fluidics continued under the direction of Professors Richardson, Lee, Brown, and Wormley. Professor Lee directed several projects in fluidics, including two doctoral theses completed this year: one doctoral candidate conducted a basic design and optimization study of turbulence amplifiers including both analysis and extensive measurements, and the other studied techniques for direct modulation of fluid amplifiers by electric fields. The latter thesis demonstrated the feasibility of switching turbulence amplifiers by low-power-level electric interaction. A Master's thesis student, working with Professor Richardson, is developing a miniaturized transducer to realize a low-voltage electrofluidic amplifier.

Professor Brown continued work on distributed systems, with generalized results in the areas of experimental identification methodology and computer simulation, and particularized results on unsteady turbulent flow in tubes. Experimental and analytical studies of proportional fluidic amplifiers led to a better understanding of their dynamic characteristics and limitations.

Professor Wormley continued research on the statics and dynamics of vortex-type fluidic modulators. His design procedure for vortex amplifiers was extended to dual-exit geometries and to include large pressure ratios. A doctoral thesis is under way which will develop and verify efficient dynamic models for this complex but unique flow amplifier. Professor Wormley also investigated the negative input impedance property of dual inlet vortex valves to achieve a fluidic oscillator which can be used as a pressure-insensitive temperature sensor.

Professor Richardson directed research in fluidics in the areas of

undersea stable platforms, fluid control logic for fluid suspensions, and temperature sensors.

Professors Sheridan and Ferrell continued research in supervisory remote manipulation, and worked on human performance in information processing tasks. Experiments were conducted on the effects of temporal uncertainty in sequential decision making.

Professor Adams continued his studies in kinematics, one on approximate straight-line maps for four-bar motion, and another on the lengthening and precision control of four-bar dwells. He continued studies in computer-time savings by preparation and submission (where possible) of computations in nomographic form.

**CENTER FOR SENSORY AIDS EVALUATION AND DEVELOPMENT** The feasibility of a simultaneous Braille and ink print version of a novel was demonstrated through publication of *The East Indiaman* by E. K. Meacham, thus bringing low-cost Braille within reach of the blind community.

Work on the Braille typewriter apparatus continued, and the Model 3 version of the M.I.T. High-Speed Braille Embosser evolved through re-design efforts.

Assembly and distribution of a crooked-handle folding cane was completed for evaluation purposes.

The ball with implanted sound source for blind children was field-tested at Perkins School for the Blind.

An expanded Pathsounder evaluation program was undertaken, including the training of peripatologists in Pathfinder techniques and the gathering of data for evaluation.

**DEVELOPMENTS IN COMPUTATIONAL FACILITIES** Development of computational facilities in the Department, initiated about one year ago, continued actively during the year under the supervision of Professor Richardson, Chairman of the Departmental Computer-Aided Engineering Committee. Professor Adams continued as Faculty Operations Officer and Mr. Sidell served as Technical Supervisor of the facility, responsible for system development.

The Electronics Associates 680 analog computer, acquired late last year, was installed in the facility and complemented with a high-speed display system. A quasi-hybrid system using the A/D conversion equipment developed last year was implemented to provide sampling and digital plotting of analog computer results.

The IBM 1130 digital machine is operated by the Department as part of the M.I.T. Information Processing Services Center. A variety of user



conveniences are provided, including student consultants and limited batch processing. Of particular note are: the ACCESS system, developed under the supervision of Professor McClintock, which permits individuals with no programming experience to utilize standard programs; and EXPORT, developed by Professor Rosenberg, which permits the direct simulation of physical dynamic systems without explicit use of equations.

Academic usage of the facility grew rapidly in the Department this year; approximately 12 subjects in the Department now utilize the 1130 in some capacity. The machine has been particularly useful in teaching of machine computation, and next fall a new subject in introductory programming will be offered. Research use of both the analog and digital machines has grown less rapidly but should be stimulated by planned software improvements in the 1130, by development of hybrid capability, and by improvement of linked operation with the large central digital computers.

Funds were secured for completion of the hybrid computer hardware and for development of graphic display capability. This equipment will be delivered in the summer and will be installed and developed during the coming year. It provides the basis for new curriculum development in analog/hybrid computation for instrumentation and control.

#### **STUDENT ACTIVITIES**

##### **STUDENT SECTION,**

##### **THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS (A.S.M.E.)**

The Student Section of the A.S.M.E., with Professor Wilson as Faculty Advisor, held approximately weekly meetings during the fall term on technical and other topics.

##### **PI TAU SIGMA**

Seminars on matters of current concern will be held at the society's national meetings, due in large part to the efforts of Smith T. Wood and the M.I.T. chapter, which is preparing a seminar on ethics in engineering for the 1969 meeting. At M.I.T., the chapter organized discussion of graduate schools and graduate study and assisted with the departmental open house. New, computer-tabulated subject and instructor evaluation forms were introduced. Based on the results of these, a comprehensive critique of the required undergraduate subjects, mentioned earlier in this report, was written to help in departmental planning.

##### **AWARDS**

The following awards were presented in May at the annual Awards Dinner organized by Professor Lent, assisted this year by Professor Wilson.

For "outstanding ingenuity in mechanical engineering," the de Florez Award was presented to Donald T. Scholz, while Donald D. Scarlett and Nancy E. Page were given honorable mention.

Silent Hoist and Crane Company Materials Handling Awards were provided by the Wunsch Foundation for the best papers in the field of production, materials handling, or machine design related to materials handling. This year the awards were won by Robert L. Jeffcoat, Robert A. S. Lee, Felix M. Mascolo, Jay A. Mackro, Adrian Bejan, and G. Thomas Gibson.

The Ed Wellech-Corning Glass Works Awards for students in the subject, Engineering Design and Manufacture, went to Joseph S. Eckerle and James G. O'Connell for the best design projects and to Stephen M. Rock, Frederick W. Young, and Peter J. Wender for outstanding manufacturing reports.

The Engineering Projects Laboratory Showcase Award for an outstanding demonstration or display was given to the Guideway Project group.

Robert G. McGregor won a Karl Taylor Compton Prize for his analytical essay on the required subjects in the Department, based on the Pi Tau Sigma evaluation survey.

Woodie C. Flowers won a Ralph R. Teeter Award of the Society of Automotive Engineers, Inc. (SAE).

#### STAFF

##### NEW MEMBERS OF THE FACULTY

Dr. C. Forbes Dewey Jr., formerly an Assistant Professor at the University of Colorado, joined the Fluid Mechanics Laboratory as an Associate Professor.

Padmakar P. Lele, M.D., Ph.D., received a joint appointment as Associate Professor of Experimental Medicine in the Departments of Mechanical Engineering and of Nutrition and Food Science. He had been Technical Director of the Medical Acoustics Research Group at the Massachusetts General Hospital.

Dr. John B. Heywood, who had worked as a research associate at M.I.T. while getting his Ph.D. in 1965, returned as Assistant Professor in the thermodynamics group. He came from the Central Electricity Generating Board in England, where he had worked on magnetohydrodynamic power generation.

Dr. Thomas J. Lardner came into the applied mechanics group as Assistant Professor. He had previously held that rank in the Department of Mathematics at M.I.T.

Dr. Richard F. Salant, formerly Assistant Professor at the University

of California at Berkeley, joined us as Assistant Professor working in the Gas Turbine Laboratory on problems of fluid mechanics and combustion. He received his Sc.D. at M.I.T. in 1967.

Dr. William J. Shack, who had been Assistant Professor at the University of California at Berkeley, joined the mechanics group in the rank of Assistant Professor. He received his Bachelor's degree at M.I.T. and his doctorate at Berkeley in 1968.

After receiving his Ph.D. from M.I.T., Dr. Daniel E. Whitney joined the controls group as Assistant Professor.

Two new research associates joined the Fluid Mechanics Laboratory: Dr. V. Sreedhara Murthy and Dr. Samuel W. Radcliffe.

Charles E. Barringer became the new administrative officer of the Department. He had been Assistant Administrative Officer in the Center for Materials Science and Engineering.

#### LEAVES OF ABSENCE

Professor Backer was on sabbatical leave during the year. He spent the time writing, studying, and planning.

Professor Berg was a visiting fellow during the spring term in the Department of Mechanical Engineering at The University of Sheffield.

Professor McClintock's sabbatical year was devoted to research at M.I.T. and Harvard, writing, and corresponding with colleagues.

Professor Rabinowicz spent the spring term as visiting professor at the Technion — Israel Institute of Technology, giving lectures and guiding research.

Professor Stickney was a visiting associate professor and visiting research engineer in the Department of Aerospace and Mechanical Engineering Sciences at the University of California at San Diego during the spring term.

Professor Cook, as Advisor to the Birla Institute of Technology and Science, spent most of the year in India, involved in curricular, research, and administration development.

#### RESIGNATIONS

The Department notes with regret the resignations of several faculty and staff members and expresses appreciation for their many valuable contributions during their years at M.I.T.: Associate Professors Steven A. Coons, Ferrell, and Karnopp; Assistant Professors Gerstmann, Nayak, and Rosenberg; and Research Associates Escudier and Murthy. Our first administrative officer, James H. Eacker, who set an admirable model for his successors to come, also resigned.

## SCHOOL OF ENGINEERING

### VISITING STAFF

Gheorghe Borila, from the Bucharest Polytechnical Institute, was a Visiting Engineer, working with Professor Rogowski in the Sloan Laboratory.

Professor George B. Damianov, Vice Rector of the Higher Institute of Mechanical and Electrical Engineering in Sophia, was a guest in the fibers and polymers group.

Dr. Jean-Marie Georges, who received his Sc.D. from the University of Lyon, was a Visiting Engineer in the Surface Laboratory.

Dr. Suzue Ishii, Associate Professor at the University of Electro-Communications in Tokyo, continued during the fall term on her appointment as a Visiting Associate Professor in the Acoustics and Vibrations Laboratory.

Dr. James C. M. Li, Staff Scientist at U.S. Steel Corporation and Adjunct Professor at Columbia University, spent a few weeks with the materials group.

Dr. Edward Y. Leung, Assistant Professor at Southeastern Massachusetts Technological Institute, worked with Professor Orowan in the materials group as a Visiting Engineer during the summer.

Dr. Gajendra Singh, Assistant Professor at Birla Institute of Technology and Science, spent the year here as a Visiting Assistant Professor, doing research in combustion and heat transfer.

Andre Pellissier-Tanon, from the Commissariat a l'Energie Atomique, in France, was a Visiting Engineer in the materials group.

Dr. Gee Tsang, Lecturer at the University of Guelph, was a Visiting Engineer in the fluid mechanics group.

### STAFF ACTIVITIES AND AWARDS

Professor Adams served as editor of "Mechanism News," a section of *Mechanical Engineering News*, sponsored by the American Society for Engineering Education (A.S.E.E.).

Professor Backer was appointed to the Editorial Board of the *Journal of Fiber Science and Technology*, and to the Library Resources Planning Committee of the Harvard-M.I.T. University Information Technology Corporation. He continues to serve on the Board of Trustees of the Textile Research Institute and on the Editorial Board of the *Journal of Composite Materials*. He was elected a vice president of the Textile Institute, an England-based professional organization with worldwide membership.

Professor Baumann was active in the Systems Engineering Curricula Subcommittee of the Institute for Electrical and Electronics Engineers (I.E.E.E.) and has organized a project sponsored by the National Science Foundation and A.S.E.E. to assemble a dictionary of urban engi-

neering projects suitable for systems engineering courses and thesis projects.

Professor Berg presented two papers at the International Congress of Rheology in Kyoto and acted as the chairman of the session on fracture. He also presented a paper at the Symposium on High Performance Composites and acted as chairman of the session on Physics and Mechanics of Damage.

Professor Bergles was co-chairman of the Symposium on Two-Phase Flow Instrumentation held at the 11th National Heat Transfer Conference.

Professor Brown was active in the Fluidics Committee of the A.S.M.E. and is chairman of the honors subcommittee.

Professor Emeritus Samuel C. Collins received an honorary doctor of laws degree from St. Andrews University in 1967. This year he was elected to the National Academy of Sciences and also received the Gold Medal of the American Society of Mechanical Engineers, the highest award of that society.

Professor Crandall served as chairman of the Applied Mechanics Division of A.S.M.E. He also served on a National Academy of Sciences-National Research Council (N.R.C.) panel to select NSF Fellows and gave invited lectures at Clarkson University and McMaster University.

During the spring term, Professor Den Hartog was a Visiting Professor at Old Dominion College and made a lecture tour in Yugoslavia under the auspices of an agreement between the Academies of Sciences of the U.S.A. and of Yugoslavia. He also received the New England Award for "Engineer of the Year" from the Engineering Societies of New England.

During the past year, Dr. Philip Drinker served as secretary of the joint Harvard-M.I.T. Committee on Engineering and Living Systems, and was made a member of the Task Committee on Biological Flows, Engineering Mechanics Division, Fluid Mechanics Committee, American Society of Civil Engineers. He also was appointed director of the Blood Gas Laboratory of the Peter Bent Brigham Hospital, and was recently named head of the newly formed bio-engineering division of the Department of Surgery.

Professor Fay was appointed by Mayor White as chairman of the Air Pollution Control Commission of the City of Boston. He continued his service as a member of the National Aeronautics and Space Administration (NASA) Research and Technology Advisory Subcommittee on Fluid Mechanics and concluded his terms as chairman of the American Institute of Aeronautics and Astronautics Technical Committee on Plasma-dynamics and member of the Steering Committee of the Symposia on Engineering Aspects of Magnetohydrodynamics.

Professor Glicksman received the Robert T. Knapp Award for an out-

standing original paper published by the Fluids Engineering Division of the A.S.M.E. He also received the A.S.M.E. 1969 Melville Medal. He continues as a member of the A.S.M.E. Fluid Mechanics Committee.

Professor August L. Hesselschwerdt Jr. received the Distinguished Service Award of the American Society of Heating, Refrigerating, and Air Conditioning Engineers.

Professor Karnopp received the Louis E. Levy Medal from The Franklin Institute.

Professor Keck continued as a member of the Office of Scientific Research Physics Review Panel. He also was invited to serve on the board of editors of the *Journal of Statistical Physics*.

Professor Keenan was a delegate to the Seventh International Conference on the Properties of Steam at Tokyo in September. He was the John Orr Memorial Lecturer of the South African Institution of Mechanical Engineers and lectured at the Universities of Witwatersrand, Cape Town, Stellenbosch, and Durban.

Professor Lee served as editor of a book, *Fluid Control-Components and Systems*, published by the Advisory Group for Aerospace Research and Development, North Atlantic Treaty Organization (NATO). Professor Richardson also was a contributing author to this book which resulted from a lecture tour on the subject in several NATO countries.

Professor Leehey gave a course of lectures on aerodynamic sound at the Technical University of Berlin.

Professor Lele was a panel member of the International Brain Research Organization of United Nations Educational, Scientific, and Cultural Organization (UNESCO), an ad hoc referee for the Medical Research Council of Canada and for the *Journal of Physiology*. He presented an invited lecture to the American Institute of Ultrasonics in Medicine.

Professor Mann presented several formal papers on the "Boston Arm" here and abroad, as well as many informal presentations on the same subject. He joined a National Academy of Engineering Committee on the Interaction of Engineering with Biology and Medicine. He formed and is chairing in that organization a subcommittee on Sensory Aids, defining a national program relating engineering to the rehabilitation of the blind and deaf. He is a consultant in engineering science to the Department of Orthopedic Surgery of the Massachusetts General Hospital, Associate Editor of the *I.E.E.E. Transactions on Biomedical Engineering*, and retired after six years as a member of the National Research Council Committee on Prosthetics Research and Development. He has accepted an appointment as a member of the N.R.C. Committee on the Skeletal System.

Professor Mann is president of the board of directors of the Catholic Guild for All the Blind and chairman of its Research Committee. He continues as a member of the Advisory Council of the National Joint Braille Authority and chairman of the Technical Committee on standards for the production of reading materials for the blind and visually handicapped of the American Accreditation Council. He is also an advisor to the Commissioner for the Blind in Massachusetts. Professor Mann is a consulting editor on engineering design for the McGraw-Hill Encyclopedia of Science and Technology.

Professor Orowan was elected a member of the National Academy of Sciences.

Professors Paul and Wilson, with Professors Samuel B. Bodman III and Adel F. Sarofim of the Department of Chemical Engineering, presented a one-day symposium on solid wastes management under the sponsorship of Technical Forum Associates.

Professor Paynter chaired an open forum on automatic control at the Winter Annual Meeting of the A.S.M.E. He is also currently serving as the Honors Chairman of the Fluid Transients Committee of the A.S.M.E. Fluids Engineering Division.

Professor Pierce presented an invited lecture on acoustic-gravity waves to the Boston Chapter of I.E.E.E. on Antennas and Propagation.

Professor Probststein was elected a corresponding member of the International Academy of Aeronautics and Astronautics, was appointed an Editor of the *Journal of Statistical Physics*, and was appointed to the American Institute of Aeronautics and Astronautics (A.I.A.A.) Fellow Grade Committee for the selection of A.I.A.A. Fellows.

Professor Richardson and Mr. Sidell received an award from the Lubrication Division of A.S.M.E. for the Best Paper of the Year-1968 for their paper, "A Step-Bearing Accelerometer with Pneumatic Signal Output." Professor Richardson continued as chairman of an A.S.M.E. Technical Panel on Transportation and a member of the Research Committee on Lubrication. He is also papers review chairman for the A.S.M.E. Automatic Control Division. In April he spent one week as an invited guest of the Mechanical Engineering Department of the University of Utah. In the summer of 1968, he lectured in fluid power control at the Instrument Society of America Gordon Research Council and at a special summer course at Oklahoma State University.

Professor Rightmire is a member of the A.S.M.E. Research Committee on Lubrication.

Professor Shapiro continued his activities on educational films as a member of the National Committee for Fluid Mechanics Films. He serves

on the editorial board of the new book series, "Annual Review of Fluid Mechanics."

Professor Sheridan served as chairman of the 1969 NASA-University Conference on Manual Control held at M.I.T. and continued as editor of the I.E.E.E. *Transactions on Man-Machine Systems*.

Professor Prescott A. Smith served on the A.S.M.E. Metal Working Activities Committee, and as chairman of the Metal Cutting Fluids Technical Division and member of Sectional Committee B89, Dimensional Metrology.

Professor Snyiuta is a member of the American Society of Lubrication Engineers' Indexing Committee.

Professor Toong served as a member of the Editorial Advisory Board for the new publication, *Combustion Science and Technology*.

Professor Wilson taught at an A.S.M.E. course on the fluid dynamics of turbomachinery at Iowa State University in the summer of 1968. He held the first M.I.T. Urban Fellowship and worked full time during the fall term and part time during the spring for the Special Legislative Commission on the Massachusetts Bay Transportation Authority. He assumed chairmanship of the A.S.M.E. Urban Technology Committee, for which he is organizing two symposia at the Winter Annual Meeting on transportation and solid-waste management.

An international competition for manpowered land transport, which was initiated 18 months ago by Professor Wilson with the help of the journal, *Engineering*, attracted 74 entries from several countries.

Professor Yannas was appointed a member of the ad hoc Committee on Biological Materials of the Biomedical Engineering Society.

ASCHER H. SHAPIRO

### **DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE**

A popular subject for campus discussion is "student involvement." Even the words have taken on a new meaning. At one time, a student was thought to be involved if he was sincerely interested in going to class, listening quietly, and doing further study on his own; in other words, he was involved with his subjects. At some later stage, students became more involved with faculty, though usually in a restricted, social sense, through a departmental softball game, a clambake on Plum Island, or visiting at faculty members' homes. Such social involvement is in the American, if not the European, tradition and is to be commended, but many of today's students interpret involvement in a different way. At the



very least, they mean the opportunity to share in discussions which deal with educational matters such as the structure of the curriculum, or the rules and regulations under which students must operate. Some would like an authoritative voice in whatever judicial process is required to effect changes in the educational structure. The extent to which students should be consulted on curricular affairs, in particular, is an issue that has aroused a great many passions. While the faculty are not to be regarded as law enforcement agents, they should not be asked to abdicate the responsibility to give another generation the benefit of their own accumulation of experience. Prior acquisition of knowledge and tempering of opinions through experience do not automatically produce a stolid conservative, even though some S.D.S. rhetoric would indicate otherwise.

In the past year, there has been a decided increase in the level of student involvement within the Department of Metallurgy and Materials Science. If the increase does not seem spectacular, it is probably because in a small department the students are less apt to feel left out of things, even when they are not really involved in the affairs of the department to a significant extent. An additional factor is that the graduate students outnumber the undergraduates. Hence, involvement of undergraduates in laboratory work and research takes place in an atmosphere of kinship with the graduate students, who are more numerous and often more accessible than the faculty. The advantages of such associations far outweigh the possible danger that a department heavily engaged in research may neglect its undergraduates.

An important factor in the past two or three years has been the changing role of the Student Metallurgical Society (S.M.S.). It is no longer a little technical society, with sporadic meetings addressed by an invited speaker. Instead, its leaders have organized their own feedback committees to canvass student opinion of subjects of instruction and the whole curriculum in general, and have provided enthusiastic help for freshman orientation and Open House projects. Largely in response to their expressed opinions of the curriculum, an ad hoc committee, chaired by Professor Morris Cohen, with membership drawn from younger faculty members and the student body, has been formed to give education in materials science, and the present curriculum in particular, an extensive review. Nor have the graduate students been idle. While they have been active in the S.M.S., their own Graduate Council has been busy with classroom feedback work, examination of the minor and language requirements for the doctorate degree, and the compilation and reproduction of a guide to research apparatus and facilities within the Department. The latter is of especial use to new graduate students who are unaware of the many service facilities available.

On the social side, the S.M.S. continued its successful steak fries and added monthly, Friday evening social hours, which were well attended, to the extent of taxing the facilities of the John Chipman room.

#### UNDERGRADUATE INSTRUCTION

The most significant change in the undergraduate school does not primarily concern Course III students. Professor John Wulff, aided by Professor August F. Witt in particular, and by Professors Bernhardt J. Wuensch and Keith H. Johnson, introduced his new freshman subject, 3.091, Introduction to Chemistry of the Solid State. The subject was taught both terms, attracting a total of about 280 students. Recitations were conducted largely by volunteer faculty members, rather than by teaching assistants, though it is doubtful that this practice can be maintained in the next academic year with the increased enrollment that is predicted. The subject has now been adopted as one of the five chemistry subjects that may be used to satisfy the freshman chemistry requirement. This action follows a faculty vote not to accept a proposal of the Committee on Educational Policy that chemistry be no longer an Institute requirement.

Professor Robert M. Rose is responsible for a new elective undergraduate subject, 3.19T, Techniques of Metal Sculpture, which was introduced last fall and which has an interesting history. Anthony J. Zona, the technician in charge of the welding laboratory, is an amateur sculptor, whose work with junk materials, displayed in the laboratory and in display cases in the adjoining corridor, attracted a good deal of attention. After the appearance of an article in "Tech Talk," Mr. Zona was persuaded by a number of students to give informal instruction in joining techniques. Professor Rose was sufficiently impressed by the strength of student interest that he and Mr. Zona developed the present subject. The students hear a number of guest lectures to give them some background in the materials they use, but the real attraction is the opportunity to do creative, artistic work of their own. Enrollment has had to be limited and freshmen are presently given preference. From the departmental point of view, an added attraction is the presence of some students from Wellesley.

Professor Merton C. Flemings introduced a project-type laboratory into 3.141, Science of Materials, a subject taken by students from the Departments of Mechanical Engineering and Aeronautics and Astronautics. The large numbers make this an ambitious undertaking but the students are appreciative.

Undergraduate seminars, involving 38 students, were offered by Professors Harry C. Gatos and Witt, on semiconductor crystal growth, Professor Wulff, on superconducting alloys and surgical implant alloys, Professor

David L. Holt, on superplasticity, and Professor Robert E. Ogilvie, on X-ray and electron optics.

Undergraduate enrollment in Course III remained steady at 56 students, with 14 Bachelor's degrees awarded. The latter number is small, since many students elected to study for a double S.B. degree or a combined S.B. and S.M.

The Dow Chemical Company prize for the best undergraduate thesis was awarded to Judith K. Jenkins for a very fine thesis, done under Professor Wuensch's direction. The Metallurgy and Materials Prize for the outstanding junior was presented, at the last meeting of the sponsoring Boston Section, American Institute of Mining, Metallurgical, and Petroleum Engineers, (A.I.M.E.), to David T. Patten.

#### GRADUATE INSTRUCTION

Professor Koichi Masubuchi of the Department of Naval Architecture and Marine Engineering taught 3.36, Welding Engineering, in the absence of Professor Clyde M. Adams.

The requirements for the doctorate degree have been modified this year following the decision of the Committee on Graduate School Policy that reading knowledge of foreign languages will no longer be an Institute requirement. After a good deal of discussion, a large majority of the graduate students recommended, and a smaller, but significant, majority of the faculty voted, to remove the language requirement. It is expected that some students will, as part of their minor requirement, elect to make a serious study of a foreign language.

Graduate student enrollment was a little lower this year, at 145 Regular and seven Special Students. There are many uncertainties, attributable to General Hershey, about the intake of new students for next year, but present indications are that enrollment will remain reasonably steady. Advanced degrees awarded from September, 1968, through June, 1969, totaled 11 Master's and 38 doctorates.

#### GRADUATE RESEARCH

Full descriptions of graduate research programs are available in the Annual Report of Research in Materials Science and Engineering, prepared by the Center for Materials Science and Engineering. It is not, however, possible to give any feel for the complete activities of the Department in the past year without describing some of the more significant research findings.

#### PHYSICS OF SOLIDS

Professor Benjamin L. Averbach has extended his work on spin correla-

tions in magnetic materials from detailed studies of single crystals of MnO and NiO to work on CoO. It has been established that short-range, antiferromagnetic order in these materials exists well above the critical temperature, but the situation is complicated by the presence of both magnetic twin and spin domains. The development of long-range order from these modulated structures is being further investigated. Spin correlations are also being measured in permanent magnet materials, and attempts are being made to correlate the magnetic parameters with the spin arrangements.

Professors Roy Kaplow and Averbach have established structures for vitreous and crystalline selenium and are now studying selenium-arsenic alloys. The structures are determined from X-ray diffraction data which are used to obtain radial distribution functions, corrected by an iterative computer method. It has been shown that relatively small static displacements of atoms are sufficient to convert the crystalline structure to the observed vitreous form.

Professors David J. Sellmyer and Averbach are studying quantum oscillations in the transverse magnetoresistance of lead and dilute lead-indium alloys. The oscillations have been shown to be true Shubnikov-de Haas oscillations. De Haas-Van Alphen measurements have also been made on lead and lead-indium alloys to establish further features of the Fermi surface. Similar studies are being made of changes in the Fermi surface and electron scattering in beryllium alloyed with small amounts of copper. Continuation of Professor Sellmyer's work on the Fermi surface of gold-antimony compounds ( $\text{AuSb}_2$ ) has shown that, while the nearly free-electron Fermi surface model has topological properties consistent with observed open orbit directions, it does not explain some other important features of the Fermi surface. It has been concluded that such a model will not represent, even approximately, the Fermi surface of  $\text{AuSb}_2$ . Measurements on metallic fluorite compounds, such as  $\text{AuAl}_2$ , indicate significant departures of the real Fermi surface from the nearly free-electron model. Professor Sellmyer is making further studies of thermoelectric power in magnetic alloys with some interesting results.

Professor Johnson has developed a Green's function technique for the approximate calculation of the molecular orbitals of complex polyatomic and macromolecules. Applications are currently being made to sulphur and chlorine oxygens and it is hoped that, eventually, helical macromolecular systems such as DNA can be studied. Professor Johnson has also developed a new theoretical model for determining localized impurity and surface electronic states and their effects on the band structure, density of states, and Fermi surface of the host crystal. A Green's function method

is also being used to determine, from first quantum principles, the electronic energy bands and Fermi surfaces of alloys. Work has been completed on compounds such as beta-CuZn, beta-AuZn, and beta-NiAl.

Professors Kaplow and Averbach have made further developments in computer programs, originally applied to amorphous selenium, which make them sufficiently precise to be used for calculations on high-density liquid metals. Some interesting initial results have been obtained for liquid lead; the model is perfectly crystalline, apart from the random removal of sufficient atoms to reduce the average density to that of the liquid.

Professor Kaplow is also measuring the energy distribution of X rays which have suffered inelastic scattering in single crystals of beryllium as a function of the scattering direction in the crystal. In collaboration with Professor Cohen, he has also continued his studies of the Mössbauer spectra in alloys of iron with interstitial elements. The specimens for study are produced by splat quenching, which allows the formation, in suitable compositions, of unusual phases, and inhibits the diffusion-controlled rearrangements which occur in ordinary quenching. The Mössbauer spectra appear to allow identification that is more definite than X-ray diffraction in alloys which contain a number of different imperfect structures. The technique is now being applied to provide more detailed characterization of structures produced by rapid cooling in alloys, and to resolve questions about the rearrangement of carbon atoms during the cooling of martensite.

In collaboration with Dr. John W. Brackett, Professor Kaplow is developing a new version of MAP, the on-line system for numerical analysis. A language processor has been written which will allow the new system to include, in equation-like format, multiparameter operators, conditional choices, and one-, two-, or three-dimensional functions.

Professor Simon C. Moss, with Professor John W. Cahn, has been using the Kratky camera to study phase separation or spinoidal decomposition in initially single-phase multicomponent glass systems. The kinetics of the process are of considerable interest and results will be compared with the theory of Professor Cahn. Some related work is also beginning on density fluctuations in polymer films.

Professor Moss and Dr. Josef F. Graczyk have used the scanning electron-diffraction attachment, which they constructed for use with a J.E.M. electron microscope, to look at the effect of inelastic scattering on the diffraction patterns of aluminum and gold films. Plasmon losses have also been measured in aluminum, and the effect of alloying on the plasma energy has been investigated for alloys of aluminum-zinc.

## PHYSICAL METALLURGY

**STRENGTHENING MECHANISMS** Professor Cohen has examined further the isothermal nucleation of the martensitic transformation in iron-nickel-manganese alloys. The objective is to establish the nature of the pre-existing embryos or preferred nucleation sites. Current results indicate that such singularities are normally too few in number to be seen by transmission electron microscopy. Hence the number of nucleation sites in the parent phase is being varied by plastic deformation, with measurement of nucleation kinetics by electron microscopy. The role of carbon as an impurity in influencing the nucleation rates is being given special attention.

In Professor Cohen's joint investigation with Professor Kaplow, using the Mössbauer technique, the interpretation of some of the results on the environment of carbon atoms in iron-carbon martensites is clouded by the possibility of carbon redistribution at room temperature prior to measurement. The splat-quenched specimens are now being subcooled immediately in liquid nitrogen and measurements carried out before they warm to room temperature.

Professor Cohen had previously shown that a new iron-carbon solid solution, based on hexagonal close-packed iron, can be retained by splat quenching. The unit cell corresponds to  $\text{Fe}_{12}\text{C}_3$ . The phase is stabilized by the presence of silicon, but extremely rapid cooling rates are necessary to retain it and attempts to produce it in bulk quantities have not proved successful.

Professor Cohen's work on strain hardening at high plastic strains, attributable to subgrain formation, is being studied further to improve the efficiency of hardening by this mechanism. The efficiency depends on the inhibition of dynamic recovery, and if this can be suppressed, very high strength levels may be attained by this type of plastic deformation. Professor Cohen has also established that the ausform strengthening of iron-nickel-carbon martensites can be explained by an increase in dislocation density and carbon-pinning of these dislocations. The role of carbide-forming elements in strengthening, on the supposition that carbide precipitation may contribute, is now being studied.

Professor John F. Breedis has been studying the mechanical properties of titanium alloys and relating these to the deformed structures, including dislocation arrangements, twinning, and stress-induced martensite developed during shock deformation and normal rates of straining. Examination of martensite in titanium-molybdenum alloys shows that there are two kinds, one of which contains essentially no internal structure, whereas the other contains dislocations and stacking faults. The latter is found in alloys containing higher concentrations of molybdenum. Professor Breedis has also examined the omega phase in titanium-vanadium alloys

and verified that it is hexagonal in structure and forms by a diffusion-controlled nucleation and growth process during quenching and aging. It has also been demonstrated that the omega phase is not a transition phase.

Thermodynamic calculations, using a regular solution approximation, show a positive heat of mixing for titanium-vanadium and titanium-niobium alloys but a negative value for titanium-molybdenum alloys. This indicates a tendency for phase separation in the vanadium and niobium alloys and a tendency for ordering in molybdenum alloys. So far, experimental investigation has not revealed any spinodal decomposition in the titanium-niobium alloys, although such a phase separation would be indicated. Professor Breedis has also shown that stress-induced martensite in titanium alloys is hexagonal, close-packed in structure, and not twinned body-centered cubic or tetragonal.

The effect of shock deformation on the structure and tensile properties of titanium and titanium-molybdenum alloys is also being studied. In both unalloyed titanium and a titanium-molybdenum alloy, enhanced strength values are attributed to the simultaneous occurrence of phase transformation and deformation during passage of a shock wave. Professor Breedis is also continuing his work on the deformation of hexagonal close-packed alloys such as those containing ruthenium. Attempts are being made to obtain single crystals of the alloys using a floating zone technique. Professor Breedis has shown that, in fatigue of titanium alloys, a well-developed cell structure develops close to the saturation stress, but saturation occurs after fewer cycles in the finer-grained commercial-purity titanium.

**THERMODYNAMICS OF METALLIC SYSTEMS** Professor Michael B. Bever has derived equations for the heat effects of additions of mixtures of multi-component phases to a solution, in terms of the enthalpy interaction coefficients. By these equations and the measured composition dependence of the heat effects on addition of mixtures of silver-cadmium solid solutions and elemental gold to liquid tin-rich solutions, values of the enthalpy interaction coefficients in tin-rich solutions at 541°K were obtained. Analysis of the results in terms of regular solution theory and quasi-chemical theory suggest that, near the melting point of the solvent, association in the solution becomes important.

Professor Bever and Dr. Ahshaya K. Jena have measured the heats of formation of silver-rich, silver-cadmium solid solutions by tin solution calorimetry. The relative partial enthalpy of gold at infinite dilution in bismuth and bismuth-tin alloys at 620°K has also been measured. Calori-

metric and X-ray measurements on metastable phases of gold-tin alloys prepared by splat cooling are also continuing.

Professor Bever has found a correlation between changes in short-range order in copper-aluminum alloys and initial yielding, characterized by a yield drop which depended on the degree of order. The annealing behavior of cold worked silver-magnesium alloys has been studied; it has been found that the recovery process in a 50.5 per cent magnesium alloy is due to the restoration of order and dislocation annealing. The recovery process in a 44.2 per cent magnesium alloy is interpreted as vacancy-promoted ordering.

**PHASE TRANSITIONS IN SOLIDS** Professor Cahn is continuing his studies on the theory of spinodal decomposition and has shown that ternary phases can be unstable to spinodal decomposition and ordering simultaneously, an untenable possibility in binary alloys. In experimental work on phase separation and crystallization in barium silicate glasses, both electron microscope and low angle X-ray measurements are being made. Theoretical work on the X-ray scattering to be expected from particles with a diffuse interface has also been carried out.

In their comprehensive study of nucleation involving condensed phases, Professors Cahn and Kenneth C. Russell have shown that the usual assumption of interface equilibrium is not valid in the cadmium-zinc system and, in fact, one component increases its chemical potential upon solidification. Standard treatments of precipitate coarsening have been found to be inadequate in two respects: allowance is made neither for the effect of the volume fraction precipitate on the coarsening rate nor for fluctuations in the number of atoms impinging on the precipitate particle. The theory of coarsening is being tested by measuring coarsening rates of gamma-iron particles in a copper matrix. A theoretical analysis of the nucleation of second-phase particles on grain boundaries has led to an experimental investigation of grain boundary precipitation of cobalt from a copper-cobalt solution.

Professor Russell, in collaboration with Professor Philip G. Hill of the Department of Mechanical Engineering, has shown that condensation in vapors such as ammonia and benzene obeys the quantum-statistical nucleation rate equation, whereas condensation in H<sub>2</sub>O and CO<sub>2</sub> vapors is 10<sup>27</sup> times slower. In general, liquids of hydrogen-bonded or rod-like molecules follow the classical theory and all other fluids investigated obey the quantum-statistical equations. This behavior is being interpreted in terms of the highly oriented, low entropy surfaces of hydrogen-bonded liquids. Laser light scattering has been used to measure droplet size dis-



tribution in a study of the coarsening of water droplets in a supersonic nozzle.

Professor Russell has also begun an investigation of electron irradiation. Iron wires are irradiated at liquid helium temperatures and the nature of damage is deduced from a study of annealing kinetics.

**HIGH-TEMPERATURE METALLURGY** Professor Nicholas J. Grant's research on dispersion strengthening, using oxides, has been extended to intermetallic and other hard phases such as carbides. Work on iron-beryllium oxide alloys has resulted in mechanical properties, up to 1,400°F, superior to those of both commercial ferritic and austenitic stainless steels. Further work on dispersion-strengthened copper alloys of the copper-aluminum- $\text{Al}_2\text{O}_3$  type has produced some of the highest-strength alloys ever reported. The alloys are oxidation resistant and stable even after long-term exposure at 1,000°C. It has been shown generally that metallic and intermetallic dispersoids result in strengthening through bonding, whereas oxide dispersoids do not lead to strengthening but do promote stability of the structure by pinning grain and subgrain boundaries.

Professor Grant has also continued his work, in collaboration with Dr. Bill C. Giessen, on rapid quenching of liquid metals and alloys by splat cooling. Some of the supposedly amorphous phases produced have been shown, on close investigation, to be microcrystalline, involving as few as 50 to 75 atoms per crystal.

Low-cycle fatigue studies in high-purity aluminum have been continued and show important strain-rate effects even at room temperature. The scanning electron microscope has been extremely useful in studying the fracture of aluminum alloys. Fractures are initiated at large inclusions and second phase particles, or on slip bands. Serrated fatigue cracks are much more extensive during cracking propagation than was believed previously.

Professor Grant and his group have also continued to develop chromium-base alloys that are more oxidation-resistant than most other high-temperature alloys. Alloys containing finely dispersed carbides have been produced by powder metallurgy techniques, and work is proceeding on a comparison of strengthening of chromium alloys by addition of thorium oxide and intermetallic phases such as  $\text{Cr}_2\text{Ti}$ . Problems with nitrogen embrittlement are one of the stumbling blocks to progress with chromium alloys.

**ELECTRON OPTICS** Professor Ogilvie's work on metallic meteorites has suggested that a cooling model involving low internal pressure is respon-

sible for the development of the particular Widmanstätten patterns observed. Plessite areas in meteorites are being chemically analyzed with the electron microanalyzer, modified to allow quantitative analysis at low carbon levels in an iron matrix. Carbon concentrations as high as 1 per cent have been measured in plessite in a meteorite in which the bulk carbon concentration is only 0.03 per cent.

Techniques for improving the efficiency of X-ray detection are being developed for use in analyses in which volumes with submicron dimensions are of interest. This work is necessary if elemental distributions within cells are to be studied, a matter of interest in the microanalysis of biological specimens. Professor Ogilvie has also been developing methods to resolve interferences between elements, due to multiple-order X-ray diffraction, in electron microanalysis. The technique consists of a two-channel pulse-height analysis in which both elements are analyzed simultaneously from the same detector. The problem is of great interest in the phosphorus-fluorine interference which is a continued subject for biological study.

**NUCLEAR MATERIALS** Professor Thomas O. Ziebold has examined selected fracture specimens in the scanning electron microscope and microprobe analyzer. Fracture surfaces in some steels have been shown to include a relatively high density of manganese sulphide inclusions; copper appears to segregate preferentially with the sulphides. This finding is significant since, for the first time, a technique has been developed for observing the chemical microstructure of a fractured surface.

Work has begun on the neutron-bombardment hardening of iron alloys and on proton bombardment to study (n,p) reaction effects in iron. Proton bombardment does increase the surface hardness of iron significantly, but defects attributable to radiation are not observable by thin film transmission electron microscopy.

The electron microanalyzer is being used to study the redistribution of alloy elements near fusion welds of nickel-base alloys, in an effort to establish the cause of microcracking. Grain-boundary segregation has been shown to be caused by solidification of a two-phase structure near the weld molten zone.

#### CHEMICAL AND PROCESS METALLURGY

Professor John F. Elliott has completed a study of the electrochemical and thermodynamic properties of sulfides of the refractory metals. The free energy of formation of a number of the sulfides has been measured with an EMF cell using calcium chloride as electrolyte. The effects of

temperature and sulphur pressure on the conductivity of some of the sulfides have also been measured and results indicate that they show n-type conduction because of metallic interstitials.

In collaboration with Professor Emeritus John Chipman, Professor Elliott is measuring the thermodynamic properties of solid alloy systems. Dr. Shiro Ban-ya completed an extensive study on the effects of temperature and carbon content on the activity of carbon in iron-carbon alloys. Dr. Marc Onillon and Professor Barry H. Rosof are measuring the effect of alloying elements on the carbon content of austenites saturated with graphite. Working with Professor Elliott, Professor Hiroshi Sakao from the University of Nagoya, Japan, developed a novel EMF cell using a silica-saturated lithium silicate electrolyte and employed the cell in measurements of the activity of silicon in alpha and gamma iron and in silver-silicon alloys.

In a study of inclusions in steels, supervised jointly by Professors Elliott and Flemings, the influence of metal composition and cooling rate on the composition and morphology of oxysulfide inclusions has been determined. The observed structures of solidified samples can be explained in terms of a model which assumes that small droplets of the nonmetallic liquid are isolated from the metallic liquid by dendrites during the solidification process. Thus, the sulphur content of droplets formed late in solidification is very high. Tatsura Kuwabara from Japan, working with Professors Flemings and Elliott, is developing an experimental method to determine precisely the liquid fraction of a partially solidified steel sample prior to quenching to room temperature. The method is being used to study the effect on inclusion formation of additions of sulphur to liquid steel before and after deoxidation.

Professor Elliott is also studying the factors that determine the rate at which particles of solid iron, iron-aluminum alloys, and iron-silicon alloys dissolve in liquid iron. The solution rate is being measured under controllable conditions of liquid metal flow. Professor Elliott is also investigating the convective motion of interdendritic liquid in a partially solidified ingot due to density differences resulting from composition and temperature differences in the ingot.

In other work, measurements of heat flow patterns in the electroslag remelting process, using a small pilot system, are compared with predictions obtained from a theoretical model. The same basic theoretical model is also being used to predict the temperature distribution in the hearth refractories of a blast furnace and the temperature distribution in the electrode of an electric arc furnace.

With Professor Elliott, Dr. Thorvald Engh, from the Technical University at Trondheim, Norway, is studying heat transport processes in grate-

sintering and pelletizing. Professor Engh is also analyzing the dynamic character of closed-circuit comminution processes.

Professor Thomas B. King is investigating the structure of phosphate melts containing up to 10 mol per cent  $\text{SiO}_2$ . Quenched glasses are dissolved in water and the phosphate ion chain lengths are analyzed by paper chromatography. Analyses show that the silicophosphates contain shorter phosphate chains than the binary phosphates. The distribution of chain lengths shows unambiguously that silicon enters the phosphate chains near the middle and, on hydrolysis, produces a breakup into two equal portions. Professor King has also started work on the kinetics of electrode reactions in calcium-aluminate melts, which are of the type used in the electroslag remelting of alloys. The most interesting reactions are those involving sulphur and oxygen but, so far, attempts to study the kinetics of those reactions have not been successful.

**SURFACE CHEMISTRY** Professor Philip L. de Bruyn has studied the interfaces nickel-oxide, aqueous solution, and nickel-hydroxide, aqueous solution in an attempt to understand the kinetics of the establishment of the electrical double layer. The work has been extended to the interface between lead dioxide and aqueous solutions. A theoretical study of the surface thermodynamics of adsorption and the wetting process has also been completed. Professor de Bruyn has also investigated the growth, dissolution, and transport properties of hydroxy-apatite and related materials.

**CORROSION** Professor Herbert H. Uhlig is continuing his work on copper-nickel alloys with respect to the property of passivity. He has found that the electronic structure of these alloys correlates with the corrosion resistance and that predictable passive properties can be obtained by adding significant amounts of certain alloying elements. The added element is an electron-acceptor, such as iron or cobalt, which favors passivity, or an electron-donor, such as aluminum or gallium, which causes loss of passivity. The data support the point of view that passive films are largely adsorbed oxygen rather than metal oxides.

Professor Uhlig has also found that corrosion fatigue in steels, at stresses below the fatigue limit, occurs only when the general corrosion rate of the steel is above a critical value. It is possible that corrosion rates above the critical value induce plastic flow of the steel and accelerate the fatigue process. Pitting corrosion of aluminum in saline media has been found to occur only above a critical potential that varies with chloride-iron concentration but is not especially sensitive to temperature or pH. A simple method for measuring critical potential has been developed. Nitrates, sulphates and acetates added to chloride solutions shift the critical

potential to more noble values and, in sufficient concentration, act as effective inhibitors of pitting corrosion. The mechanism of inhibition appears to be one of competition between extraneous ions and chloride ions for adsorption sites on the aluminum surface.

#### CERAMICS

**KINETIC PROCESSES** Professor Wuensch, in his research on grain boundary diffusion, has already measured the diffusion rate of thallium in single-crystal, bicrystal, and polycrystal potassium chloride. Enhanced diffusion along grain boundaries has been observed in some, but not all samples. The degree of enhancement is probably influenced by impurities at the grain boundaries. Bicrystals synthesized in the presence of water vapor show marked enhancement of the degree of grain boundary diffusion.

Professor Robert L. Coble has initiated a study of the effect of pressure on grain boundary self-diffusion. In this work also single crystals, bicrystals and polycrystals will be used. Professor Coble has also monitored the sintering kinetics of alumina by a surface measurement technique. An increase of gas permeability in fine-grained alumina compacts was observed when they were heated below the temperature of initial shrinkage. These measurements are presented as a surface area decrease and are related to surface diffusion in alumina by means of models which assume sintering of spheres or cubes.

Professor W. David Kingery has studied the densification of nonstoichiometric magnesium-aluminate spinel powder compounds. To achieve good densities, compounds must be intimately mixed and a coprecipitation technique has been found to be useful. It is hoped that the role of solid solubility in the sintering of more complex ceramic systems will be better elucidated. Drastically different sinterability of powder compacts results when the ratio of alumina to magnesia in the spinel is varied.

Professor Donald R. Uhlmann has done further work on crystallization and melting kinetics in glasses and has found that, in the case of germanium dioxide, for example, nucleation of the crystalline phase takes place at external surfaces. Crystallization then proceeds by the propagation inward of the crystal-liquid interfaces. No internal nucleation of the crystalline phase is ever observed. Growth rates depend on the atmosphere in which the crystallization is carried out as well as upon the original melting conditions of the glass; this may well be due to different water contents or states of reduction.

**STRUCTURE-PROPERTY RELATIONSHIPS** Professor Wuensch has made a number of crystal structure studies, including work on refining of the atomic coordinates for single-crystal  $As_2S_3$ . He has found that the sup-

posedly tetrahedral compound  $\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$  accepts fairly large amounts of mercury into solid solution. Mercury normally assumes an octahedral coordination, but no site of this type is occupied in the structure. The conditions under which complex superstructures, based upon a rock salt-like array of atoms, form in certain lead-containing sulfides, are also being looked at. It is of interest that only a few of the many possible compositions are stable.

Professor Wuensch is also studying a phase transformation in  $\text{CuAgS}$  which involves an unusual amount of energy. An analogous transformation in  $\text{Cu}_2\text{S}$  occurs in which both copper diffusion rates and conductivity increase by several orders of magnitude. Professor Wuensch is also making measurements on some of the sulfosalts, including those of bismuth and antimony. The crystal chemistry of these materials is very complex and there are associated experimental problems which have been responsible for the fact that very few structures are known.

Professor Coble has been investigating the incorporation of boron and phosphorus in vapor-deposited beta-silicon carbide. Boron and phosphorus are introduced into crystals, grown by the decomposition of methyltrichlorosilane by adding diborane or phosphine to the gas stream. There are anomalous density changes in the undoped crystals seeming to result from free carbon in the deposit, which would not be predicted under equilibrium conditions.

Professor Coble, in a continuing study of dislocation velocities in fluo-rite structure compounds, has moved to investigate the effect of divalent impurities on the relative behavior of edge and screw dislocations in calcium fluoride. It is hoped eventually that an elucidation of the drag mechanism controlling dislocation motion in these materials will be obtained.

Professor Kingery has been studying the solubility mechanisms of dopants in single-crystal aluminum oxide, grown by the Czochralski or Verneuil methods. Density changes and lattice parameter shifts caused by the dopants are the measured quantities. Crystals sometimes appear to be single phase when they actually contain very fine particles of a second phase that changes the expected density. It has been determined that vanadium ions go into solution in  $\text{Al}_2\text{O}_3$  in the trivalent state, whereas silicon ions go into solution with the formation of aluminum vacancies, and titanium ions go into solution in both trivalent and tervalent states.

**STRUCTURE AND PROPERTIES OF NONCRYSTALLINE SOLIDS** Professor C. Joseph Mogab has grown single crystals of cubic silicon carbide epitaxially on crystals of silicon by direct carburization. Thicker films sometimes show a single crystal pattern superimposed on a weak polycrystal-

line pattern of cubic SiC, which suggests that at some critical thickness the epitaxial relation is lost, possibly in an effort to relieve stresses generated in the overall growth. Preliminary kinetic data suggest that the growth rate is diffusion-limited, but the rate is much higher than one would expect, based on the extrapolation of measured self-diffusion coefficients for one of the hexagonal polytypes of silicon carbides. Professor Mogab's previous study of the kinetics of annealing of noncrystalline silicon carbide have been extended to noncrystalline silicon and germanium. The rate law for non-crystalline silicon carbide annealing is logarithmic and is consistent with a thermally activated process distributed in activation energy.

Professor Uhlmann's studies of flow and relaxation processes in glass-forming liquids have shown that the flow behavior of even simple liquids, such as salol, glycerine, and certain more complex organic liquids, is more complicated than can be accounted for by the usual theoretical treatments, particularly with regard to the variation of viscosity with temperature. A molecular theory for viscous flow in a glass-forming liquid is being developed.

Professor Uhlmann has also studied the effects of phase separation on the viscosity of glass-forming liquids. The viscosity of a sodium-silicate glass has been found to depend mainly upon the morphology of the separate phases. Non-Newtonian flow is to be expected under these conditions. The relations between phase separation and other glass properties, such as density, elastic modulus, and thermal expansion, are also being studied. Professor Uhlmann has also carried out measurements of dc conductivity and dielectric relaxation in a series of simple alkali silicate and mixed alkali and alkaline-earth silicate glasses. Measurements of conductivity have been related to electron microscopic observations, and no evidence is found for the sharp breaks in the conductivity, composition relations previously reported by other workers.

**MATERIALS SYNTHESIS AND PREPARATION** Professors Kingery and Wuensch have been investigating a number of different methods for preparation of ceramic materials, including freeze-dry preparation of mixed oxides, a technique which prevents segregation of salts and produces quite homogeneous oxides. This technique is especially useful in the preparation of spinels. Professor Wuensch has also studied chemical vapor transport as a technique to form small, highly perfect crystals suitable for diffraction studies. The transport of zinc sulfide by iodine in a closed system is being investigated, to gain some insight into the kinetics of the process and the optimization of variables before proceeding to more complex systems. Professor Kingery has also developed techniques for static

growth in an encapsulated system in two different temperature zones for the preparation of wüstite from iron bromide crystals. The material will be used for thermal gradient property studies.

**POLYMERIC MATERIALS** Professor Uhlmann has worked on the effect of crystallization conditions on the morphology and properties of crystalline polymers such as polyethylene, polypropylene and nylon. An optical hot stage that permits separate variation of the temperature gradient and the rate of growth has been constructed and is used for direct observation of the crystallization process. The crystallization of several polymers under high pressure also has been studied. Extended chain conformations result in materials such as polyethylene and polypropylene. The effect of high pressure on amorphous polymers has also been looked at and it has been shown that, while increases in density of up to 1.5 per cent are obtained in polymethyl methacrylate treated in the glass transition region, a much smaller increase in density and little or no change in other properties such as specific heat result from high-pressure treatment in the glassy state. Professor Uhlmann has also investigated amorphous polycarbonate with respect to its flow behavior. Annealing after deformation to strains of the order of 50 per cent produces complete recovery. However, on subsequent testing the samples are characterized by small values of the yield strength.

#### ELECTRONIC MATERIALS

Professors Gatos and Witt have continued their work on the characterization of elemental and compound semiconductor surfaces, especially in germanium, gallium arsenide, and gallium sulfide. A new technique for field effect measurement was developed and large signal, alternating current, field effect experiments in the dark and under illumination were made on "real" germanium surfaces after a heat treatment in ultra-high vacuum. After prolonged heating at 520°K, surfaces of germanium were slightly p-type, exhibiting three to five times higher density of traps than prior to heating. Higher temperatures rendered the surfaces more p-type but caused essentially no change in the density of traps. The observed changes in the electrical properties were correlated with the results of desorption experiments in which a mass spectrograph was employed. The total surface charge was found to increase linearly with the amount of desorbed water. Real gallium arsenide surfaces were also investigated by the field effect experiment in the temperature range from  $-50^{\circ}\text{C}$  to  $+200^{\circ}\text{C}$ . The observed surface states appeared to be of crystal defect origin rather than of the abrupt termination of lattice periodicity. In connection with the surface characterization of CdS, a study of the etching



characteristics was made. While relatively smooth surfaces can be obtained with an etching solution of potassium dichromate and sulfuric acid, the etching procedure results in pronounced conical etch-pits on the cadmium surface. Improved flatness was obtained by using concentrated orthophosphoric acid at temperatures in excess of 160°C. The disadvantage of this process is its lack of adequate reproducibility and its sensitivity to surface orientation.

A crystallochemical approach to electronic materials has been made by Professors Gatos and Witt and, in superconductors, an investigation to determine the effect of second-phase precipitation on the critical temperature and critical current density of well-annealed binary transition metal alloys was undertaken. The systems chosen were tantalum-rich zirconium and zirconium-rich vanadium alloys. Optical and electron microscopy and X-ray diffraction techniques have been used to investigate the nature and distribution of the precipitating phase in these alloys. Aging in the tantalum-zirconium alloys enhanced the critical current density by almost an order of magnitude, and the peak in current density was found to coincide with precipitate particle size and separation of about 1 micron. Precipitation in the zirconium-vanadium system is complicated by a martensitic transformation and the data indicate that the behavior of the alloys in aging depends strongly on the degree of supersaturation.

Work on vitreous semiconductors was continued with the system arsenic selenide-antimony selenide. Optical activation energies have been found from fundamental light absorption edges, as a function of composition and temperature, using the indirect transition theory that is applicable to the system. Infrared transmission, adsorption, and reflection have been investigated as functions of composition and temperature. No absorption or reflection bands were observed.

Investigation of single-crystal growth characteristics in Czochralski-type crystal-growing systems has been continued. Polishing techniques, together with differential etching, were combined with interference contrast microscopy and multiple-beam interferometry in studies of the microdistribution of impurities in semiconductor single crystals. A linear resolution of about 2,000 Å is now achieved reproducibly. The origin of impurities discovered by these techniques has been related to growth conditions. Microheterogeneities are believed to account for anomalies in the electrical behavior of certain semiconductors. Studies of the modes of crucible and seed rotation have led to growth conditions resulting in single crystals in which no impurity heterogeneities have been observed. The work on impurity distribution in semiconductors has now been expanded to germanium with the discovery of a suitable etching technique. The effect of applied electric fields across the growth boundary in indium

antimonide and the electrical properties of indium antimonide with varying degrees of impurity inhomogeneities are currently being studied. Hall measurements show that crystal sections grown with seed rotation exhibit considerably lower carrier mobilities than sections grown with crucible rotation.

Related work on extremely pure and homogeneous materials has resulted in the preparation of radiation detectors that have resolution of less than 2 per cent for a Cs<sup>137</sup> spectrum and show no decrease in resolution upon storage for several hours at room temperature.

Professors Gatos and Witt have also carried out research on epitaxial vapor growth of silicon carbide. The etching characteristics of silicon carbide have been studied in some detail and it has been found that the etch rate of single-crystal alpha-silicon carbide in hydrogen follows an Arrhenius type of dependence on temperature. Single-crystal alpha-silicon carbide layers have been grown on alpha-silicon carbide substrates at 1,500°C. At higher temperatures the simultaneous etching rate of the substrate becomes too high for any net deposition to take place.

Professors Rose and Wulff have continued their studies of superconductivity, particularly as affected by variations in microstructure of the superconductor itself. The superconducting behavior of niobium-titanium alloys, containing 40 per cent or more niobium and with variable oxygen content, has been studied as a function of thermomechanical processing. Precipitates produced during processing seem to be responsible for an increase in the critical current density in these alloys. Such precipitates may be related to the niobium and oxygen content of the alloys. The addition of metals such as yttrium, gadolinium or thorium to niobium-titanium-oxygen alloys seems to raise the general level of the critical current density and may simultaneously improve the ductility. This is particularly significant in view of new processing requirements for the manufacture of composite magnet wires of copper and superconducting alloys.

Professor Rose has shown that severely cold worked niobium remains superconducting up to very high applied fields. This particular phenomenon is being related to the microstructure of the metal, which is being fabricated with plastic deformations of greater magnitude than have heretofore been obtained. Niobium has also been grown, in single-crystal form, in ultra-high vacuum with well-controlled oxygen contamination. Measurements of the properties confirm the hypothesis that oxygen atoms cluster in niobium even at concentrations below 500 parts per million. Professor Rose has measured the delay of the Miessner mixed-state transition in vanadium, niobium and tantalum crystals and found that, in all cases, the superheating field is more than  $H_C$ , in direct contradiction of much present theory. Professor Rose's work on superconducting com-

posites has shown that the magnetic behavior, critical fields, and critical temperatures of niobium-copper composites fit a model based on the proximity effect theory of the Orsay group and the known geometry of the composite. Laminar composites are also being investigated.

Many thin films, for example those of aluminum, have critical temperatures much higher than the corresponding bulk material; however, some metals do not exhibit this phenomenon. Although it is reasonable to attribute the high  $T_c$  behavior to abnormal structure, no direct evidence on the nature of the structure is presently available. Electron diffraction and electron microscopic measurements are being made on aluminum films, in an effort to delineate the structural requirements for high  $T_c$  in thin films.

#### MATERIALS PROCESSING

Professor Wulff's work on surgical implant alloys was initially directed to development of alloys which showed superior corrosion resistance in body fluids. It has been found that, for implants in which wear may also be a problem, as in assemblies for replacement of hip joints, the properties of alloys with respect to small-displacement wear are at least as important as the corrosion properties. In particular, it has been found recently that alloys which show superior corrosion resistance in body fluids do not necessarily show superior wear resistance and attempts are now being made to develop alloys which will show improved performance in both respects.

**CASTING AND SOLIDIFICATION** Professor Flemings has established a metal crystal growth facility, as part of the Center for Materials Science and Engineering, and a recent addition to the facility is a plasma-arc unit for growing metal, ceramic composite crystals.

Research on crystal growth has included continuation of studies of the structure of crystals grown in a magnetic field, of the growth of composite crystals, and of crystals grown under conditions of high-velocity fluid flow. Convection may be inhibited by the application of a magnetic field and induced by crossed electric and magnetic fields. Significant improvement in the perfection of eutectic alloy crystals is obtained by inhibition of convection. In related work, two-phase alloys of noneutectic composition are being grown under steep temperature gradients at a slow rate, and it has been shown that two-phase "composites" are produced at compositions far removed from the eutectic. While the initial work has been on lead-tin alloys, current work is on aluminum alloys of structural interest. High-velocity flows are studied by conducting solidification in the space between two counter-rotating cylinders. The velocity gradient is enhanced, by about two orders of magnitude, by the superposition of a strong magnetic field.

Work on growth kinetics of metals solidified at large degrees of undercooling has the aim of investigating the effects of undercooling on the structure and solute redistribution. The present experimental work is on samples of about 100 grams undercooled in glassy containers and levitated metal droplets solidified by splat cooling between two accelerated metal platens.

Research on macrosegregation, under Professor Flemings' direction, comprises both analytical and experimental studies. A general analytical expression has been obtained for segregation caused by flow of solute-rich liquid to feed solidification and thermal contraction. It has been shown that inverse segregation and centerline segregation can be understood as limiting cases of the analysis. The direction of fluid flow with respect to solidification isotherms is currently under investigation and experiments agree qualitatively and quantitatively with the analytical results. Work on dendrite morphology has recently included the effect of electromechanical methods of disintegrating dendrites during growth.

Professor Flemings has initiated some work on the influence of solidification variables on the tendency of alloys to rupture during solidification, a phenomenon known as hot tearing. While the phenomenon has been studied previously, there are many features that are not well understood. A further study is also being made of heat flow during the solidification of alloys that solidify over a wide temperature range. The aim is to optimize local cooling rates at critical temperatures during ingot solidification so as to minimize local dendrite arm spacing.

**DEFORMATION PROCESSING** Professors Walter A. Backofen and Holt have continued their research into the mechanism of superplasticity and the forming of superplastic alloys. The development of a superplastic magnesium alloy that shows clear metallographic indications of diffusional flow has helped to elucidate the role of such flow in superplastic deformation. It has been recognized that the stretching of superplastic (pseudoviscous) sheet is amenable to mathematical analysis, perhaps more so than the stretching of conventional sheet metals. Analyses have been made of the bulging of circular blanks, clamped around the periphery, and of the flow of a sheet into V-grooves.

Professor Holt has been working on a theory of dislocation cell formation, based on the consideration that dislocation clustering is analogous to the clustering that occurs during the spinodal decomposition of a saturated solution. The theory describes a number of the experimental observations that have been made on cell size in plastic deformation.

**COMPOSITES** Professor James W. Mar of the Department of Aeronautics and Astronautics, with Professor Wulff and Dr. Lawrence A. Shepard,

has continued studies of fiber composites. The tensile properties of aluminum, aluminum-nitride eutectic fiber composites have been studied over a range from room temperature to about 600°C and at varying strain rates and fiber spacings. The effects of strain rate and fiber spacing on the tensile properties were small compared to those due to fiber denuded grain boundaries and fiber orientation spread. The average values of tensile strength for samples with good fiber alignment considerably exceeded the best commercial aluminum alloys above 300°C.

Copper-iron composites, with iron-fiber diameter and copper matrix spacings from 250 microns to 0.25 microns, and fiber volume fractions from 6 per cent to 85 per cent, have been fabricated by a bundle-and-draw method. Recrystallized samples were tested in tension at temperature from 77° to 373°K. The maximum composite strength is found at intermediate fiber volume fractions, with fiber and matrix dimensions in the 0.25 micron range. The strength of such composites exceeds the strength of recrystallized iron wire. The effects of reactions between fiber and matrix, particularly with regard to compound formation, depend on whether the filaments themselves are ductile and notch-insensitive. For brittle filaments, severe strength degradation occurs if as little as 1 per cent of compound forms between the aluminum and molybdenum fibers.

#### ARCHEOLOGICAL METALLURGY

Professor Cyril S. Smith, with a grant from the National Endowment for the Humanities, has been working in collaboration with Professor Arthur R. Steinberg of the Department of Humanities. Recent research on Luristan steel has shown that the Luristan smiths were very skilled in mechanical shaping but did not use the basic techniques of welding or hardening steel by quenching. Professor Smith has made an analysis of the wire-making techniques used by the makers of bronze Cretan armor, the techniques of the Sasanian silversmiths, and the methods used in making the earliest type of blue faience, which may well be a direct antecedent of glassmaking and metallurgical alloying techniques.

Professor Steinberg has been doing studies on bronzes from the ninth and eighth centuries B.C., including some as late as the fifth century B.C. The bronzes exhibit various methods of joining large sections, which give valuable insights into the working techniques of the classical bronze sculptors and founders. Examples which have seemed to be soldered joints have turned out to be well-executed fusion welds with a joining metal of the same composition as the casting.

Miss Heather N. Lechtman has been working on pre-Columbian metal artifacts, both copper-base and silver alloys. Examination techniques have been chiefly metallography and electron microprobe analysis. The

results indicate that the north Peruvian Indians used gilding techniques unique to that area, in which a ternary alloy of silver, copper, and gold was employed and the silver and copper removed by a cementation process, leaving the surface enriched in gold.

#### STAFF

Professor Cyril Stanley Smith, one of the most noted physical metallurgists to be associated with this or any other Department, retired this year. He will continue, part-time, to study the contribution of technology to history and to maintain his laboratory for archeological metallurgy. Professor Smith was a pioneer in the characterization of metallic structures, on the scale of the light microscope, and his remarkable insight into structural form led him naturally to an appreciation of structure in nature and the arts. He founded the Institute for the Study of Metals at Chicago and has been the recipient of many honors and awards, including election to the National Academy of Sciences. Professor Smith's retirement was marked by a two-day seminar on structure at Endicott House, attended by biologists, linguists, scientists, and artists. It was a most unusual and successful affair, organized by Professor Steinberg of the Department of Humanities, Professor Cahn, and Miss Lechtman.

Following the appointment of Professor Nicholas J. Grant as Director of the Center for Materials Science and Engineering, Dr. Regis M. N. Pelloux, of The Boeing Company, and a former student of Professor Grant, joined the Department as Associate Professor of Metallurgy. His interests are in high-temperature alloys, fracture mechanics, and scanning electron microscopy for fractographic studies. One such study won for Professor Pelloux the Grand Prize in the American Society for Metals Metallographic Competition last year.

Professor Clyde M. Adams, on leave of absence during the year, resigned to become Pelton Professor at the University of Wisconsin at Milwaukee.

We take pride in the promotions to Professor of Robert L. Coble and Merton C. Flemings. Professor Flemings has also been appointed to the Abex Professorship of Metallurgy, and his series of papers on solidification won for him the Mathewson gold medal of The Metallurgical Society, A.I.M.E. Professor Coble spent a sabbatical year at the University of Florida, making progress on a textbook and winning a place in the National Sailing Championships (Lightning class). Other well-deserved promotions, to Associate Professor, went to Kenneth C. Russell, Bernhardt J. Wuensch and Donald R. Uhlmann.

Professor Morris Cohen has been elected Vice President of the American Society for Metals and will assume the Presidency next year.

Dr. Joseph T. Blucher, former Research Associate, was appointed Visiting Lecturer to teach a subject to graduate students on instrumentation for research.

Dr. Thorvald Engh, from Trondheim, Norway, spent the year with Professor Elliott, making notable contributions to dynamic analyses of metallurgical systems and participating in teaching. Dr. Hiroshi Sakao, from Nagoya University, Japan, also spent the year doing research with the chemical metallurgy group, while Dr. Marc Onillon returned to France. Dr. Robert Mehrabian replaced Dr. Theodoulos Z. Kattamis as Research Associate in Professor Flemings' laboratory.

Dr. and Mrs. Tibor Nemeth, from Hungary, were Visiting Scientists with Professors Gatos and Witt. Dr. Thomas Thomsen, from Darmstadt, Germany, spent another year with Professor Backofen's group.

Donald L. Guernsey, in charge of the Central Analytical Facility of the Center for Materials Science and Engineering, retired this year. Mr. Guernsey, who joined the Department in 1938, was universally respected as an analyst whose results were invariably precise and reliable. Most of the pioneering work in the physical chemistry of steelmaking, by Professor Chipman and his students, would have been impossible without the contributions of Mr. Guernsey and his staff. He is succeeded by Louis Carrara.

The Colloquium series, arranged by Professor King, dealt with modern research techniques and included lectures by a number of faculty members. The Robert S. Williams lectures were delivered, fittingly, by Professor Chipman, previous Department Head and pioneer in the high-temperature chemistry of metallic and slag solutions. Professor Chipman took as his title, "Studies in the Chemistry of Metallic Solutions."

It is pleasant to note that, in a year of mounting student unrest, the Visiting Committee for the Department, talking informally to a number of Course III students, reported that student-faculty relations seemed to be excellent.

THOMAS B. KING

## DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

The Department was in its 75th year of operation during this academic year, having been established as an independent Department in 1893 to provide in the United States the first place for education in naval architecture — an education which in those days could only be obtained in Europe.

During those 75 years, the program has responded to the various demands and the developments in the marine industry. It was deemed fitting for the 75th year of operation to concentrate our efforts toward the planning and development of an educational program in light of the foreseeable challenges of the next decade: a program which aims at developing in the student basic knowledge of engineering sciences as well as the capability for imaginative engineering for the ocean environment.

During the year, we have carried out this intense planning and concentrated effort to create an educational program in the Department which will meet the requirements of the next decade. In this effort, we were motivated and guided by the following major factors:

1. The impact of the Marine Resources and Engineering Development Act, which leads to a much stronger interest in the utilization of the oceans
2. The urgent requirement for overcoming the weaknesses in the U.S. maritime industry and U.S. marine transportation systems
3. The necessity for using the "systems" approach in order to appraise technical innovation in the marine field in the context of its sociopolitical effects.

President Howard W. Johnson, in his address to the Society of Naval Architects and Marine Engineers at the November, 1968, Annual Meeting in New York, described the problem of engineering education as follows:

... a major problem of engineering education in general, and especially as it applies to the marine field, is the need to retain for the student a close touch to reality, amidst the vast and complicated sea of theoretical ideas and material that he must absorb.

I feel that, through heightened concern for social issues and through his respect and knack for decision making and implementation, the engineer of the future can be expected to make a unique contribution at the center of the societal concerns of our times.

It is this philosophy described by President Johnson which sets forth our goals and our approach to the education of the students entrusted to us.

**STUDENTS**

In 1968-69, the Department student body consisted of 19 undergraduates and 123 graduate students. These were distributed as follows:

Undergraduate	16	United States
	3	Foreign
Graduate		
XIII and XIII-B	19	United States
	12	Foreign
XIII-A	66	United States
	12	Foreign
Ocean Engineering	13	United States
	1	Foreign



DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

It should be noted that a number of students in both the XIII and XIII-A programs are also candidates for Ocean Engineering degrees, but for the purposes of the above listing, the highest degree for which a student is a candidate determined his field.

The graduate students that entered the Department in 1968-69 were received from the following sources:

	<u>XIII, XIII-B, and Ocean Engineering</u>	<u>XIII-A</u>
M.I.T. baccalaureate programs,		
Course XIII	4	0
U.S. Coast Guard Academy	1	4
U.S. Naval Academy	0	12
Webb Institute of Naval Architecture	1	0
All other U.S. colleges	13	4
Foreign colleges	5	2
Total	<u>24</u>	<u>22</u>

These students selected their programs in such a way that 33 became candidates for degrees in the field of naval architecture and marine engineering, 12 in ocean engineering, and one in shipbuilding management.

Considering the student body as a whole, the candidates for the various degrees were distributed as indicated below. It should be noted that one student may be a candidate for more than one degree.

<u>Degree</u>	<u>Total number of candidates</u>
S.B., N.A.M.E.	16
S.M., N.A.M.E.	44
S.M., O.E.	19
S.M., S.B., and S.M.	2
Mar. Mech. E.	4
Nav. Arch.	6
Nav. E.	78
Ocean E.	3
Ph.D.	9
Ph.D., O.E.	5
Sc.D., N.A.	1

**FACULTY**

The previous section gave statistics of the student body to illustrate their varied background and wide range of interests. The major resource available to the Department with which to shape the students into engineers is the faculty. The faculty of the Department is listed below. It may be

noted that nine of the 22 teaching faculty joined the Department last year.

The new faculty members fill needs in three areas:

1. Structures and structural mechanics: Professors Koichi Masubuchi, Norman Jones, and Alaa E. Mansour; and William S. Pellini, a Visiting Lecturer
2. Marine transportation systems: Assistant Professor John W. Devanney and Franz A. P. Frisch, a Visiting Lecturer
3. Marine hydrodynamics: Assistant Professor Damon E. Cummings

## EDUCATIONAL PROGRAMS

### UNDERGRADUATE

Planning is essentially complete for the restructuring of the undergraduate program. The aims of the restructured program are to seize and hold the interest of the undergraduate students at an early stage of their educational experience, and to broaden the program to encompass the areas of interest of those entering the ocean engineering field.

The emphasis is on engineering for the ocean environment and is not restricted to ship design.

The first step in setting up this program was to determine what should be common background to every undergraduate student of the Department, whatever his interests. Beyond these requirements, sequences were recommended in various optional fields, keeping certain basic subjects as requirements additional to the Institute requirements. The fields considered essential are: basic mechanics, thermodynamics, mathematics, fluid mechanics, and materials science.

The various fields of major interest are included as optional sequences of subjects. Any of these sequences may be negotiated with the Faculty Advisor or individual sequences may be arranged for students with particular interests: structures for the marine environment, fluid mechanics, energy conversion, ship design, oceanography, controls and instrumentation, legal and economic studies, and biological applications.

The new undergraduate program offers the students subjects in this Department at the beginning of the sophomore year to increase participation and identification with the Department. Experience indicates that this is essential.

The subjects, however, are in seminar and computer applications and are not requirements. A laboratory subject is also included in the sophomore year to introduce the students to the available Department facilities.

As an experiment, we offered a new subject in the spring term, 1968, Water, Air, and Interface Vehicles. The intent of this subject is to make available to freshmen, who presumably do not have a clear view of engi-

Table I Department of Naval Architecture and Marine Engineering Faculty

Present Rank	Name	Year	Major area of interest
Assistant Professor	John W. Devanney	1969	Ocean transportation system
Assistant Professor	Damon E. Cummings	1968	Hydrodynamics
Professor	Capt. Dean A. Horn	1968	Naval systems
Assistant Professor	Norman Jones	1968	Structural mechanics
Assistant Professor	Alaa E. Mansour	1968	Structures
Associate Professor	Koichi Masubuchi	1968*	Materials
Professor Emeritus	Norman J. Padelford	1967	Ocean engineering public policy
Assistant Professor	Jerome H. Milgram	1967	Hydrodynamics
Associate Professor	John N. Newman	1966	Hydrodynamics
Professor	Alfred H. Keil	1966	Ocean engineering
Associate Professor	Cdr. Sherman C. Reed	1966	Naval systems
Professor Emeritus	Jacob P. Den Hartog	1962*	Structural mechanics
Professor	Patrick Leehey	1962	Acoustics
Professor	Ernst G. Frankel	1959	Production analysis
Professor	John H. Evans	1947	Structures
Professor	Justin E. Kerwin	1957	Hydrodynamics
Professor	Philip Mandel	1957	Vehicle design
Professor	Martin A. Abkowitz	1949	Hydrodynamics
Associate Professor	S. Curtis Powell	1948	Power systems
Visiting Lecturer	Franz A. P. Frisch	1969	Ocean transportation system
Lecturer	William S. Pellini	1969	Materials
Visiting Lecturer	Miguel Junger	1966	Acoustics

\* Dual appointments

neering as a discipline different from science and mathematics, an engineering elective subject taught by senior engineering faculty. Obviously, one of the motives of the Department was to attempt to attract to engineering and more particularly to this Department, uncommitted freshmen who might otherwise drift into other fields because of insufficient familiarity with engineering.

While both the Department of Aeronautics and Astronautics and this Department are strongly vehicle-oriented, no single subject has ever been offered at M.I.T. that treats airborne and waterborne vehicles on a common basis and includes consideration as well of vehicles such as hydro-foil craft, air cushion vehicles, planing craft, and surface ships, operating at the interface between air and water. It was thought that such a subject, if offered, might arouse the interest of the uncommitted freshmen.

In preparation for offering the subject last spring, we launched a rather large advertising campaign aimed at the entering freshmen. We attracted 28 of them, of whom 16 completed the subject. Of these, two have enrolled in this Department this year, three have enrolled in Aeronautics and Astronautics, five in Electrical Engineering, three in Physics, and three are still undecided. Based upon this experience, it cannot be said that we succeeded in attracting a significant number of students to naval architecture.

This year, with hardly any advertising, 20 students initially registered for the subject, with 14 apparently intending to complete it. Of the 20, five are uncommitted freshmen, and the rest are undergraduate students, five of whom are registered in this Department. Other departments represented include Mechanical, Civil, and Electrical Engineering. At M.I.T. this year, all freshmen are asked to evaluate each of their subjects at mid-term. One comment concerning this subject was, "I find this course very interesting. It describes things from an engineering view rather than a scientific one, which is a refreshing change." This is precisely the tone that we hoped to convey in the subject.

#### GRADUATE (COURSE XIII)

During the last year, the Department reviewed its graduate program. Several changes and additions have been made in the past, but two specific reasons made it necessary to carry out a complete and thorough review:

1. The structures program in the Department has always been confined to applied structural analysis and design and has not covered the structural mechanics aspect. Furthermore, the XIII-A Program depended on two introductory structural subjects by Professor Eugene Mirabelli of the Department of Civil Engineering, who is retiring in June, 1969. With the addition of three new faculty members to the Department structures

group at the beginning of the current academic year (Professors Jones, Mansour, and Professor Masubuchi), a stronger and more comprehensive structures sequence can be offered, interlocking with the departmental design subjects and the ship production subject now under development. In addition, a stronger interaction with the Department of Metallurgy and Materials Science can be developed.

2. Further reviews in the areas of hydromechanics design, marine transportation, and acoustics and vibration, combined with the availability of additional faculty, is leading us to consolidation of existing subjects and the establishment of a number of new subjects in these fields.

#### GRADUATE (COURSE XIII-A)

The naval construction and engineering curriculum has been given a searching review by Professors Horn and Reed to take advantage of the improvements made elsewhere within the Department, both in subject offerings and their coordination. Philosophically, the structure of the curriculum has been reduced to encourage more diverse specialization by each participating student while retaining the breadth essential to the goal of the XIII-A program — professional engineering competence signified by the professional degree. We believed that, aside from the direct application, the acquisition of this intense specialization enhances the individual as a broad professional engineer by showing him how to acquire a new specialization himself, or to best utilize or develop in others such a specialization. Consequently, the area of specialization is felt to be of less consequence than the student's personal commitment to it.

The approach to the specialization has been largely the choice of the individual, but a definite goal and coherence in the recommended curriculum have been required. The optional fields represent the area in which the Master's degree is awarded while applications subspecialties suggest a goal for a coherent curriculum plan and eventual thesis.

Early success has been achieved with this approach. One student pioneered a new optional field in that he has negotiated and developed his own program leading to a Master's degree in metallurgy. Several students have shown great interest in a Master's degree in management. Although arrangements with the Sloan School have not been completed for a degree program, emphasis is being placed in that field by some students. Yet another student is developing an application subspecialty in power systems as a part of his candidacy for a degree in ocean engineering.

#### GRADUATE (COURSE XIII-B)

In the past, an almost universal experience of the graduates of the Department was to move into positions in a variety of design-oriented engi-

neering and research organizations. It is now clear that, with the broadening of the interests of the Department, and, more basically, with the broadening of the responsibilities of the modern engineer, this situation is changing. Almost all of our future graduates will, at some time in their careers, hold management positions in which the knowledge of basic marine economics, systems analysis, and sound management practice will be as important as technical competence in ship design. At present some of our graduates are moving directly into operations research and transportation systems groups in both industry and government. Shipping and marine transportation companies, prodded by the rapid change in cargo handling technology, are expressing increasing interest in our students. The increasing importance of governmental maritime policy and government investment in marine resource development calls for a combination of engineering and economic skills.

The basic shift in the demands placed upon our students has led to a thorough review of our marine systems curricula, which in turn has resulted in the following changes aimed at unifying and intensifying our offerings:

1. The subject offerings basic to applications of operations research to marine problems have been redesigned. As now constituted, they will consist of a comprehensive survey of nonprobabilistic optimization techniques illustrated with marine applications. All marine systems students will henceforth be required to take a full subject in probability outside the Department. Formerly, probability theory was surveyed within this Course.
2. A new subject offering in ocean transportation economics has been instituted. This subject has the dual purpose of acquainting the student with the basic economics of the ocean transportation industry including the economics of maritime policy and to the economic foundations underlying sound system analysis.
3. The subject offering in marine decision processes concentrates entirely on the methodology of marine decision making and investment under uncertainty. The theory of decision making under risk is presented and applicable optimization methods developed. These are illustrated by case studies. The newly established prerequisite of a full subject offering in probability will allow this subject to be intensified.
4. The ship production analysis subject offering will be upgraded to a full nine hours per week. It will analyze various shipyard techniques, including computer-aided detailing and materials preparation, modular construction, and alternate erection and launch techniques. Shipyard layout, management information systems, and production line balancing will be studied.

5. A new subject in project control and network analysis has been prepared by Professor Frankel. Methods of network analysis and project scheduling will be presented and utilized in modeling large operational and production systems. These methods include CPM, PERT, flow graph techniques, conditional stochastic networks, and decision networks.

As a result of these changes, the Department can now offer a Master's degree with specialization in marine systems as a one-year alternative to the existing programs offered jointly with the Sloan School of Management.

#### GRADUATE (OCEAN ENGINEERING)

The Graduate Ocean Engineering Program conducted by the Department is well under way. It has stimulated substantial new interactions within the Department as well as with other departments throughout the Institute. The broadened educational program is not only of benefit to the students of ocean engineering, but also to many other students who take ocean engineering subjects as electives.

The program is based on the concept that it should lead the student to master the engineering sciences, understand synthesis and design, develop engineering attitudes, and realize the interrelation of advances in ocean engineering with the social, economic, and political environment. The final goal of the program is to develop graduates who can apply their understanding of the ocean environment and of the engineering sciences to perform imaginative engineering that can advance man's capability for greater utilization of the ocean.

As developed, the program requires a course of study built around specified and elective subjects, embracing the topics of Table II, or combinations of these. It is based on the expanding capabilities of the Department and draws on existing capabilities in other departments of the School of Engineering.

The program also benefits from the increasing strength of the Department and Woods Hole Oceanographic Institution (W.H.O.I.) in oceanography and depends on the Department of Political Science for the legal and political aspects of ocean engineering.

It should be noted that an agreement has been reached between M.I.T. and the Woods Hole Oceanographic Institution setting up a joint degree program in ocean engineering for students interested in those aspects of ocean engineering pertaining to oceanography. This is in addition to the Department's Ocean Engineering Program and the existing M.I.T.-W.H.O.I. joint program in oceanography.

Although the granting of degrees with the "Ocean Engineering" desig-

**Table II Engineering Topics Relevant to Ocean Engineering**

Topics	Surface vehicles	Submerged vehicles	Stationary floating platforms	Stationary bottom structures	Towed devices and techniques	Instrumentation	Communication and navigation
Ocean vehicle hydromechanics	*	*	*				
Waveloads			*	*			
Ocean vehicle strength analysis	*	*	*				
Strength analysis of deep sea structures		*		*	*	*	
Structural dynamics	*	*	*		*		
Structural acoustics	*	*	*	*	*		*
Motion control systems	*	*	*		*	*	*
Ocean navigation	*	*	*				*
Energy sources for ocean engineering	*	*	*	*	*	*	*
Energy converters for ocean engineering	*	*	*	*	*	*	*
Auxiliary machinery system for ocean engineering	*	*	*	*			
Information theory							*
Sonar systems	*	*	*	*	*		*
Flow noise	*	*	*		*		*
Hydroacoustics	*	*	*	*	*		
Hydroelasticity	*	*	*	*	*		
Towing and mooring mechanics				*	*	*	*
Underwater photography				*	*	*	
Materials in ocean engineering	*	*	*	*	*	*	*
Ocean waves	*		*		*	*	
Design synthesis	*	*	*	*	*	*	*
Soil mechanics				*			
Systems analysis	*	*	*	*	*	*	*

nation rests with the Department, students registered in other departments may also take any ocean engineering subjects for which they have the prerequisites. In so doing, they may orient their programs of study toward engineering for the ocean environment or add another facet to their capabilities; or they may choose to supplement regular curricula with a few ocean engineering subjects taken as electives.

Only graduate degrees in ocean engineering are offered, and we are prepared to accept qualified holders of Bachelor's degrees in physics, oceanography, and all engineering fields, or from any science or engineering background.

Eight core areas have been identified, from each of which at least one subject must be taken to satisfy the ocean engineering requirements for any of the graduate degrees. These are marine hydromechanics, dynamics,



mathematics (beyond minimum undergraduate requirements), computer use and applications, oceanography, ocean engineering structures, energy conversion, power, and propulsion; and systems engineering and design synthesis.

Most students with Bachelor of Science degrees will have fulfilled all the prerequisites for the suggested subjects from the fields above and up to one-third of those subjects.

Furthermore, a concentration of at least three elective subjects from one of the following seven areas is required: oceanography, materials, random processes, underwater communications and sensing, special ocean engineering subjects (a category allowing for special interests such as ocean bottom soil mechanics, legal and political implications, waves, and coastal processes), decision theory and optimization techniques, and systems engineering and design synthesis. Specialization in the areas of marine hydromechanics, structures, or energy conversion, power and propulsion would normally lead to a qualification for previously established graduate degrees in naval architecture and marine engineering. Nevertheless, a sufficiently persuasive selection of subjects in these areas might be accepted under the "special subject" category.

The Department started the development of five new subjects for the Ocean Engineering Program under the auspices of the Ford Foundation Program for the improvement of engineering education. Later, National Science Foundation (NSF) Sea Grant support was also obtained, and preparation of lecture notes is now nearing completion as follows:

1. Public Policy and Use of the Seas (released)
2. Ocean Engineering Structures (draft completed)
3. Hydrospace Vehicles (draft completed)
4. Motion Control of Hydrospace Vehicles (draft completed)
5. Ocean Engineering Materials (nearing completion).

#### **COOPERATIVE EFFORTS**

Buildup in cooperation with others was carried out as follows:

1. Cooperation with the Department of Political Science became possible when Professor Padelford assisted us by offering within the framework of the Ocean Engineering Program a new subject, Public Policy and Use of the Seas. He is now planning another new subject, Law of the Sea, to be offered also within the framework of the Ocean Engineering Program.
2. Cooperation with the Department of Metallurgy and Materials Sciences developed during the past year, since Professor Masubuchi joined the Department. Professor Clyde M. Adams of the Department of Metallurgy and Materials Sciences left the Institute, and Professor Masubuchi took over the welding engineering subject that had been offered by Pro-

fessor Adams. In addition, Professor Masubuchi is cooperating with the Department of Metallurgy and Materials Science by participating in the teaching of a subject which can best be described as an introduction to ocean engineering materials.

3. The Department broadened its participation in the annual spring term interdisciplinary Systems Study. A total of 13 of the 23 students were from the Department. The interdisciplinary systems engineering subject is offered in the spring term under the guidance of Professor William W. Seifert of the Departments of Civil and Electrical Engineering. The topic this year was devoted to the problem of transporting Alaskan North Slope oil to east coast United States markets. At the conclusion of the term, the students presented the results of their studies, in Kresge Little Theatre, to a large audience of outside experts from New York, Washington, Boston, and other cities. The report will be published later this year. A number of alternatives were considered for transporting the Alaskan oil, including pipelines across Alaska and Canada, tankering through the Northwest Passage, use of submarine tankers, and combinations of pipelines and tankers. The political, legal, economic, engineering, and financial aspects of removing the Alaskan oil were considered by the students in their report.

#### FRANCIS RUSSELL HART NAUTICAL MUSEUM

During this year, which marked the 75th anniversary of the founding of M.I.T.'s Department of Naval Architecture and Marine Engineering, the Hart Nautical Museum had several special exhibits pertaining to the early days of the Department. These exhibits featured computing devices, fishing boat changes during the 75 years, photographs of faculty and facilities, and M.I.T.'s navy of 1912 — the large self-propelled models *Froude* and *Fulton*. The computing and fishing vessel exhibits were featured in "Tech Talk," and *The Tech Engineering News* (January, 1969) had a good article on the computing devices.

The year's major accession was the Gordon Munro collection of plans, photographs, and models, which was donated by Mrs. Munro during the summer of 1968. Mr. Munro, a professional naval architect, was active in the Boston area from the early 1920's until his death, designing small commercial vessels and yachts.

Other accessions included plans and books from W. Hampton de Fontaine of Glenbrook, Connecticut, steamships prints, and four models that were purchased. Three of the models were of fishing vessels: a colonial vessel of about 1640, the pinky *Essex* of 1821, and the modern stern-trawler, *Old Colony*. The model of the latter was on display before the

actual vessel joined Boston's fishing fleet. The fourth model was of a local packet sloop whose design was developed by the curator from a half-model in the museum's collection.

Although not properly accessions, through negotiations extending over the past two years all the books from the Nautical Museum that were sent to the Engineering Library during the Second World War were returned, thus increasing or at least making more readily available, material useful in answering the many questions received by mail and telephone, and from numerous visitors.

Three models are now under construction for the museum: the first ocean-going tanker, the *Gluckauf* of 1885; a Scottish fishing boat of the early 20th century; and the *Froude*, with which Professor Peabody conducted resistance experiments on the *Charles* in 1912. Roderick Matheson is constructing the models of the *Froude* and the fishing vessel; plans for the latter were obtained from Scotland and proved to be for a vessel he had known as a boy.

The models of the U.S.S. *Salem* and U.S.S. *Van Divier* on loan from the Navy were recalled in October, 1968. Because of space limitations in the Institute a large, triple-expansion steam launch engine was loaned for an indefinite period to The Marine Museum of Fall River, Massachusetts.

Last year's report mentioned the treatment of five Benjamin Russell water color paintings from the Forbes Collection for an acid condition in the paper. All 21 of the Russell paintings in the collection have now been treated and framed with special backing by a professional paper conservator.

In the museum display space, the stained cloth in the bottoms of the main cases has detracted from the models. With the cooperation of the Institute's staff architect, new cloth was purchased; that under the *Christianus Quintus* has been replaced, and the other cases will be changed during the coming year.

During the past year the curator, William A. Baker, gave his usual two lectures for Professor Adams' seminar on Boston; delivered lectures on shipbuilding for the Early American Industries Association, the Maine Historical Society, and the Munson Institute of American Maritime History; and participated in a symposium on the writing of local histories at Bates College. In March he attended a symposium on historic wooden shipbuilding at the National Maritime Museum, Greenwich, England, and visited wooden-boat-building yards and the Lisbon Marine Museum in Portugal; and in April participated in a meeting of maritime historians at the U.S. Naval Institute at Annapolis.

**FACILITIES**

**SHIP MODEL TOWING TANK**

The ship model towing tank has undergone a major overhaul during the year. A new stainless steel wave-generator paddle was installed, with new solid-state electronics for actuating the hydraulic servo-valve for wave generation control. Most electronic recording devices, including the tape and chart recorders plus amplifiers, were sent to the manufacturer for complete servicing. The main carriage drive mechanism has been overhauled, realigned, and an additional multispeed gear box has been added to improve the speed range and speed selectivity, as well as to provide more convenient carriage operation. The entire hydraulic system has been completely cleaned and serviced.

Some additional electronic instrumentation has been added, such as solid state amplifiers and a RMS (Root Mean Square) meter. New wheel assemblies are being designed for the carriage in order to reduce the level of carriage vibration. As a result of the renovations to Building 48, a direct access from the new elevator to the far end of the tank has been provided. In addition, an office for towing tank staff has been made available in the basement of Building 48 near the towing tank.

Because the Towing Tank was closed for overhaul during the second term of the year, there was reduced thesis and research activity at the tank. During the time that facilities were available for model testing, quite an active test program was carried out in ship response to wave systems (especially for development work in the DX program) and propeller-hull excitation research.

**STRUCTURES LABORATORY**

As a result of a proposal submitted to NSF, an amount of \$8,000 has been allocated toward rebuilding and improving the structural laboratory. These are matching funds with \$4,000 being supplied by the Foundation and \$4,000 by the Institute. These funds will be used to obtain minimal equipment for structures research and demonstration for teaching. Further expansion for inclusion of a wide diversity of testing equipment relevant to ocean structures is planned.

**VARIABLE PRESSURE WATER TUNNEL**

The Variable Pressure Water Tunnel, which was originally built by Professor Frank M. Lewis, was completely overhauled and greatly updated over a period of five years, with support from M.I.T. and NSF. While the faculty is presently operating and some new instrumentation has been obtained, the needs for instrumentation and special measurement facilities have not yet been met. A project to provide a six-component variable

thrust measurement device coupled with a variable pressure measurement capability has been proposed to the National Science Foundation. The planning and initial preparation for this work has been carried out under support by the Institute's Sloan Fund.

#### ACOUSTICS AND VIBRATION LABORATORY

The Acoustics and Vibration Laboratory, which was developed by Professor Leehey, and which is operated jointly by the Department of Mechanical Engineering and this Department, has made substantial progress during the past few years. Additional instrumentation was made available under Ford funds, and we are now in a position to make statistical correlations of vibration, turbulence and noise measurements in this very low turbulence wind tunnel in connection with acoustics research.

#### RESEARCH

##### HYDRODYNAMICS

Seakeeping research under sponsorship of the Maritime Administration (MARAD) continued at an active pace under the direction of Professor Abkowitz. A consolidated seakeeping analysis program for use in ship design has been published and sent to MARAD. With a rather simple input with regard to hull shape and loading, the displacements, velocities, accelerations, both absolute and relative to the water surface, in several specified sea states at several ship speeds, can be calculated for many positions along the hull length. In addition, the added resistance in the seaway and the bending moment loadings are calculated. Research in ship slamming pressures and loads continued, and an investigation into response of transom sterns in a seaway was initiated under MARAD sponsorship.

Use of the programs above was made, in addition to use of our unique seakeeping test facilities at the Towing Tank, by all competitors in the Navy DX Program. The work investigating maximum motions in a seaway for destroyer types (under Navy sponsorship) is nearing completion, with interesting results obtained from the analysis of long-time statistical data in the tank.

Under the Deep Submergence Rescue Vehicle (DSRV) program sponsored by the Instrumentation Laboratory, model tests were completed and analyzed for determining the feasibility of a five-point Pitot tube for a relative directional velocity sensor, for modeling of the hydrodynamics forces and moments at all general angles of attack, and for investigation of thruster duct inflow velocity at all body angles of attack.

Also under way is an investigation of the best method for representing test data as a surface function. An analysis is being carried out to formu-

late a meaningful set of trials for test and evaluation of the control system of the DSRV.

Professor Newman is conducting research on fundamental aspects of ship waves under sponsorship of the Office of Naval Research. Aerial photographs have been made of the waves generated by the ferry boat M.V. (motor vessel) *Uncatena*, in cooperation with the Woods Hole Oceanographic Institution, and a model-scale experiment is being initiated in order to ascertain if visible scale effects can be detected. A theoretical investigation is under way, as a doctoral thesis, to examine the interactions between separated wakes and waves astern of a ship. Under the same contract, a theory has been developed to predict the maneuvering characteristics of ships in shallow water.

A new grant has been received from NSF to consider wave problems in shallow water. The first investigation being carried out under this grant is a theoretical technique for analyzing wave propagation in regions of changing depth. This research has been performed by Dr. David V. Evans, an applied mathematician from Great Britain who spent the year as a visitor in the Department.

Professor Newman is investigating the hydrodynamic pressure forces acting on a submerged object in proximity to the bottom and the free surface, under a new contract from the Naval Ship Research and Development Center. A computer program is being developed to predict the forces and moments, and parallel experiments were performed in the Propeller Tunnel.

Professor Milgram developed a partially separated airfoil analytical theory that determines the pressure distribution on a two-dimensional airfoil and in the surrounding space in partially separated flow. The theory is not yet entirely self-contained in that one arbitrary parameter must be specified, the data having been taken from experimental results. The theory helps to explain, quantitatively, the deviations of results of experiments on thin airfoils of large camber at low incidence angles and on thick airfoils of any camber at moderately large incidence angles from attached flow theories. Agreement of the theory with experiment is excellent. Applications include sails, parawings, plain-flapped airfoils, rudders, and other control surfaces.

Professor Milgram has also studied the analytical methods of sail design developed over the past nine years, and his theories have finally been confirmed by a wind tunnel experiment. This experiment was very competently executed by a graduate student as part of his Master's thesis.

Theoretical results have been obtained which indicate that certain types of flow separation, heretofore thought to be detrimental, cause an increase in ship resistance at some speeds and a *reduction* in resistance at

other speeds within the normal operating speed range of ships. Preliminary towing tank experiments have given an indication that the nature of these results is correct. If separation does indeed reduce resistance at some speeds, fuel savings at these speeds can be realized by the deployment of spoilers to induce separation. Professor Milgram is pursuing this line of research.

Professor Kerwin supervised an analytical analysis of "flapped rudders." These devices are of interest because of their potential for reducing the torque the rudder stock must withstand. The analysis results will be compared with experimental values which will be obtained in the Variable Pressure Water Tunnel in the next year. A computer program has been developed that may be useful in further analysis if the correlation of experimental and theoretical values have as high a correlation as expected.

An experimental study of the unsteady forces causing vortex-excited oscillations of large cylindrical cables was carried out under Professor Kerwin's direction. This study was inspired by the Oceanic Telescope under the support of the M.I.T. Instrumentation Laboratory. The Oceanic Telescope is an array of sensors designed to observe internal waves in mid-ocean depths.

Professor Cummings directed research on hydrofoil ship constant lift control systems. Three systems were studied: full incidence, trailing edge flap, and tab foil. It is assumed that the devices are to be applied to a constant-lift, wave-alleviated control system for an ocean hydrofoil ship.

An analysis using lifting line theory applied to large hub propellers was accomplished by a graduate student under the supervision of Professor Cummings. The results were applied to two specific cases which revealed that circulation is reduced below the optimum near the hub.

#### ACOUSTICS AND VIBRATIONS

Professor Leehey continued research into ship acoustic radiation. The first two years concerned the noise associated with steam reducer valves. The effort this year was centered upon the propeller singing phenomenon.

Research on the measurement of propeller forces in single screw ships was carried out by Professor Lewis. Measurements have been made with parent and U-type series 60 hulls with a variety of four-, five-, and six-bladed propellers. An important finding is that the total horizontal force is extremely sensitive to rudder position, so that large changes in the force level may be produced by small changes in the rudder position relative to the propeller.

#### STRUCTURAL MECHANICS

A ballistic pendulum and associated equipment were designed, manu-

factured, and erected in the Department of Aeronautics and Astronautics blast chamber under the direction of Professor Jones. An investigation was undertaken into the dynamic response of beams and plates with different support conditions and material properties. The external loads were sufficient to produce plastic flow of the material and large permanent deformations. This work is continuing with external financial support for the experimental and theoretical behavior of other structural shapes, including shells. The information gained from these studies will be useful for a wide range of engineering applications. Some specific examples are: slamming damage to ships, design of meteoroid bumpers to sustain hyper-velocity impact, automobile safety design, explosive damage to ships, and various containment vessels.

Professor Jones is also conducting a theoretical study into the elastic behavior of two cylindrical shells which intersect at an arbitrary angle and are loaded with an external bending moment. It is believed that the results of this study and other companion investigations will lead to the better design of pipelines and various other shell intersections which are encountered frequently in all branches of engineering.

An experimental and theoretical investigation is currently in progress to examine the influence of geometry changes or finite deflections on the creep or time-dependent behavior of simple structural shapes when subjected to static loads. This program is also under the direction of Professor Jones.

#### MARINE STRUCTURES

Professor Evans completed research for the U.S. Steel Company, dealing with the utilization of several steels in combination in the design and construction of ship hulls. The results of this research provided the following conclusions:

1. In the face of arbitrary hull stiffness requirements now in effect, an excess of 20 per cent in the moment of inertia requires about a 5 per cent excess of hull weight and in construction cost.
2. The more pronounced reduction in construction cost would derive from more near equalization of steel prices within the grades than from equalization of fabrication differentials.
3. The overall economic advantage of the mixed framing system over the transverse system is striking, and it prevails regardless of the steel combinations used.
4. More refined labor cost-estimating techniques are required by the industry, especially in this country, where it is such a large fraction of the total cost.
5. Confirmation was established that, when in doubt, it is better to locate



material interfaces nearer the neutral axis rather than the reverse; and the higher the strength of the steel, the smaller should be the frame spacing.

Professor Mansour directed research on the stresses developed in ice-breaker bows. The analysis compared the various methods of predicting bow loads under various ice thickness and ship speed conditions. The study then explored the various methods available for predicting stress levels in the bow structure. The study concludes that the most promising and exact method of stress analysis utilizes the finite element method.

#### MATERIALS AND FABRICATION METHODS

Professor Masubuchi directed research on the distortion in butt welds and the removal of distortion using flame straightening techniques. The butt weld investigation developed a formulation to predict the transverse shrinkage, and the degree of constraint may be useful to determine the cracking susceptibility of welded structures.

In another investigation, a comprehensive review of the fabrication history of aluminum as a shipbuilding material was undertaken in order to assess its potential for use in the Chilean shipbuilding industry.

Two XIII-A students presented the result of nearly two years of work in their chosen subspecialty, ferrocement applications, to the New England Section, Society of Naval Architects and Marine Engineers at the March meeting. Their paper title was "Ferrocement for Marine Application, An Engineering Evaluation." Extremely strong interest nationwide resulted in several reprintings for sale by the Society.

#### VEHICLE DESIGN

Professor Mandel supervised a design research project involving a modern fiber glass stern trawler readily convertible to a minesweeper for replacement of the aging New England fishing fleet. Because of strong interest, more than four hundred copies of the report have been distributed. It was presented as a Department seminar in March of this year and will be given as a paper before the Chesapeake Section of the Society of Naval Architects and Marine Engineers this fall. Strong U. S. Navy and Bureau of Fisheries interest makes actual construction a possibility.

The interest in this area of research caused Professors Mandel and Reed to encourage other graduate students to follow similar lines of research. One student, therefore, undertook a project of examining more broadly the whole area of massive metamorphosis of ships to perform different military and commercial missions. The report on this project entitled, "The Concept of a Variable Missions Ship — An Example," and a report, "The Case for Metamorphic Ships," are the results.

Professor Abkowitz directed a research study, "Emergency Ascent Tra-

jectories for Deep Submersibles.” The study derived the second-order, coupled equations of motion for a vehicle varying mass and center of mass. These were used to predict the motions of the DSRV in an emergency ascent.

Professor Newman supervised a research report including experimentation on a “Momentum Reversing Brake for Large Vessels.” This research was undertaken to evaluate scoops as a means of stopping super tankers.

#### TRANSPORTATION SYSTEMS ANALYSIS

Professor Frankel led a research project to develop a simulation model of a ship-to-shore transportation system to operate at the interface between sea and land transport systems. Different vehicles were examined and evaluated for this purpose, including landing craft, air cushion vehicles, and hydrofoils. The simulation model has been completed.

A separate study involving the analysis of cargo handling has been undertaken. Various methods of loading and unloading a wide variety of cargos at several specified port facilities are simulated.

#### OCEAN ENGINEERING

Professor Reed directed a project evaluating offshore salvage potentials and problems. The report examined the market potential, technology, economics, and legal aspects of this area of endeavor.

One of the Department’s students executed a research project studying two control schemes aimed at monitoring and controlling a diver decompression system. One scheme employs a simple on-off relay controller and a solenoid valve. The pressure error is developed by a digital computer to fix the set point and generate nonlinear compensation for a conventional analog controller. The effect of the compensation on the overall system is to cancel the nonlinear behavior of the chamber pressure during decompression.

#### STUDENT ACTIVITIES AND AWARDS

The students, on their own initiative, prepared a useful “Fact Book” to acquaint newcomers with the personnel and facilities in the Department. In addition, they organized an orientation open house for new students early in the fall term.

Throughout the fall and spring terms, an unofficial and volunteer group met for dinner and discussions one night a week. The major points of consideration included methods of increasing the communication between the students themselves and between students and faculty, and what ac-

tion the students should initiate to become more contributive to the M.I.T. community. The results were:

1. Graduate students have volunteered to serve as assistants to the Registration Officers.
2. A second "Fact Book" is going to be prepared and mailed to the new students during the summer.
3. An orientation meeting and a get-acquainted party are being organized for the beginning of the fall term.

The Department is especially proud of a XIII-A student, Michael R. Terry, USN, who was the recipient of one of the Karl Taylor Compton Awards. These awards are given in recognition and encouragement of outstanding contributions in promoting high standards of performance and good citizenship in the M.I.T. community.

The Department takes pride in the traditional awards. The Brand Award, given annually by the Society of Naval Engineers to the member of the graduating class in Course XIII-A with the highest academic standing, was received by Lieutenant David L. Luck, USNR. The American Bureau of Shipping Prize, which is awarded annually to the student with the highest scholastic achievement for the third and fourth years in either Course XIII or Course XIII-B, was received by William G. Zink.

#### SEMINARS AND SYMPOSIA

A "Workshop on Applications of Lifting-Surface Theory in Ship Hydrodynamics" was organized by Professors Kerwin, Newman, and Milgram, with financial support provided jointly by the Office of Naval Research and the Royal Netherlands Navy. About 35 participants attended from England, France, Germany, the Netherlands, Sweden, and the United States, and stimulating discussions of current research were held during a period of three days.

The Department organized a seminar series in both the fall and spring terms covering a broad range of marine-related subjects. Each series consisted of approximately 15 lectures. They proved effective in stimulating the student and faculty interests and increasing the effectiveness of student-faculty communication.

During the spring term, the Institute faculty approved cancellation of classes so the departments could organize two afternoons of student-faculty discussions. These were aimed at defining the issues of concern to both groups and laying the foundation for dealing effectively with these issues.

One afternoon of discussions was held in the Department and was attended by 60 to 70 students and most of the Department's faculty members. An improvised chicken-and-beer dinner was served from 6:00 to

7:00 p.m. and offered the advantage of continuing the discussions in small groups.

A small interested student group had prepared a tentative agenda and had asked Professor Mandel to serve as moderator for the meeting.

The agenda served to stimulate thought concerning the topics to be discussed. Discussion was very lively and moved rapidly from very broad issues (M.I.T. and the Department of Defense) to departmental issues and covered two subject areas:

1. Specific "inadequacies" such as scheduling of classes, difficulty of matching the one and one-half hour class scheduling in the Sloan School of Management with the normal class hours of the rest of the Institute, offering of summer subjects, dissemination of information in the Department, and the need for a reference library for the Department.
2. Broader issues of relevance to the Department, such as the presence of naval officers (XIII-A Program) in the Department, the Department's research contracts with the Department of the Navy, and questions such as what is the influence of the Navy on the Department and what can the Department do to introduce "social relevance" to its programs.

The meeting was extremely worthwhile and especially gratifying, since most of the questions which were brought up by the students were answered during the discussion by other students.

The two major accomplishments of this worthwhile session are the generation of a much stronger interaction and exchange of opinions among the several segments of our student body and second, a much better understanding of the students, goals, perspectives, and the mode of operation of the Department.

#### FACULTY ACTIVITIES

Professor Keil presented an invited paper called "Meerestechnik" (ocean engineering) to the Schiffbautechnische Gesellschaft (German Society of Naval Architects) in November, 1968. He was invited by the Society to present the paper, and it will be published in their journal. In June, 1968, he gave two lectures at the Technical University of Berlin (T.U.B.): "The Broadening Scope of Naval Architecture," and "Ocean Engineering at M.I.T.," as part of the M.I.T.-T.U.B. Exchange Program.

Five M.I.T. faculty members, including Professor Keil, were invited by Prime Minister Lee of Singapore to visit Singapore to make recommendations on the education program of Singapore, in light of their economic development plans. The visit took place during the first two weeks of March.

Professors Keil and Mandel were appointed to the Laboratory Advisory Board for Naval Ships of the Naval Research Advisory Committee.

#### DEPARTMENT OF NUCLEAR ENGINEERING

Both professors have made major contributions to the Board's activities this year.

Professor Mandel has been granted sabbatical leave for next year and has been appointed as a liaison scientist for naval architecture on the staff of the Office of Naval Research in London, England. He has also received an appointment as Visiting Professor of naval architecture at the University of London for the same period.

Professor Padelford presented a paper on ocean policy before the Society of Fellows at the Center for International Affairs at Harvard University. He was also appointed a founding member of the Board of Editors of a new journal, *The Journal of Maritime Law and Commerce*, to be published in New York City beginning in the fall of 1969. He continues to serve as a member of the Board of Editors of *International Organization*, published by the World Peace Foundation in Boston. Professor Padelford is active as a member of the Board of Trustees of Denison University in Ohio.

Professor Frankel was appointed to the president-elect's Task Force on Transportation, which studied the transportation needs of the country from a public policy viewpoint.

Professor Abkowitz was a member of the Seakeeping Committee of the International Towing Tank Conference (I.T.T.C.). The 12th I.T.T.C. will meet in Rome in September, 1969.

During the last academic year Commander Sherman C. Reed, USN, Associate Professor of naval engineering, served as Secretary-Treasurer of the New England Section of the Society of Naval Architects and Marine Engineers. He has been reelected for the coming year.

Dr. Miguel C. Junger, Visiting Lecturer, was appointed to the Technical Committee of Underwater Acoustics of the Acoustical Society of America.

Professor Evans was appointed to the Committee on Ocean Engineering Education for the American Society of Engineering Education.

ALFRED A. H. KEIL

#### DEPARTMENT OF NUCLEAR ENGINEERING

The broad objectives of the faculty of the Department of Nuclear Engineering are: (1) to provide advanced technical training for young men and women in the fields of engineering and applied science, related to nuclear technology; and (2) to challenge and prepare these individuals to make imaginative and productive contributions and to become technical leaders in their chosen fields of specialization. In the pursuit of these

objectives, the faculty attempts to convey to the students the conviction that the engineering method provides the means for an efficient and economic usage of our natural resources, thus making it possible for more and more people to participate in the progress of society and to enjoy the fruits of their labor. For this reason, the faculty also attempts to instill in the students an attitude of responsiveness to the needs of society, and a sense of pride in the humane rewards to be derived from a constructive career in engineering.

Technology can provide the means for the satisfaction of both intellectual and material needs of mankind, but is not a substitute for human and humane values and ideals. Today more than ever before, the distinction between means and values is most important. Technical advances have had impressive and unprecedented beneficial effects on our lives. Nevertheless, either because of lack of foresight or lack of clearly adopted and consistently pursued ideals, or both, technical advances also have had negative results on our environment and the structure of our society. The negative results, however, are neither inherent to nor unavoidable by-products of technology. For technology can respond both effectively and creatively to needs consistent with social goals and ideals, provided these goals and ideals are defined. The distinction between means and goals must be made so that "how to work for something" and "what to work for" are not mistaken for each other, to the detriment of both.

The two major unifying themes for the programs and activities of the Department are the fission reactor technology and the field of applied plasma physics. This fact is illustrated by the research projects of faculty and students, described in subsequent sections of this report.

During the past year, the number of nuclear power plants ordered by U.S. power companies has not been as large as that during each of the years 1965 through 1968. The slowing down reflects a compensation for the fact that more nuclear power units were ordered in previous years than was warranted by the normal rate of growth of demand for electricity. The same slowing down has occurred in orders for fossil fueled power stations.

Interest in nuclear energy continues to be very optimistic. All experts agree that the predictions for a large nuclear industry, described in last year's annual report, are realistic. Thus, the need for individuals with advanced training in nuclear engineering continues to be great.

The outlook for fusion power reactors has improved during the recent past. Advances in better confinement times for dense and very hot thermonuclear plasmas, and better estimates of the energy removal system from a well-confined thermonuclear plasma have resulted in optimistic views about the feasibility of a controlled fusion machine. Students con-

concentrating on applied plasma physics will, therefore, have excellent opportunities for imaginative and original engineering contributions to this developing field. In addition, they can use their knowledge in contexts of immediate practical significance such as ionospheric phenomena, thermonuclear conversion, and laser technology.

#### STUDENTS

During the past year 40 students received the degree of Master of Science, 7 the degree of Nuclear Engineer, and 21 the degree of Doctor of Science or Philosophy. The number of students in each degree category was higher than in the preceding year.

In September, 1968, enrollment in the Department was 127 regular students and 3 Special Students. About 30 per cent of the students came from 17 foreign countries. About 95 per cent of our students received their undergraduate training in professional fields other than nuclear engineering. The majority of the undergraduate professions are engineering oriented. The U.S. citizens among our students came from 84 different undergraduate schools; only 8 of these men did their undergraduate work at M.I.T. The broad diversity of national, professional, and academic backgrounds of our students provides a very stimulating environment for the activities of the Department.

The demand for nuclear engineering graduates from our Department continues to remain high. Many of our graduates are now employed by the electric utility companies which are operating, have ordered, or are in the process of ordering nuclear power plants. This trend is especially gratifying, since we expect our graduates to make important contributions to this vital industrial sector.

#### FACULTY

In addition to their teaching and research efforts, which are described later, the faculty of the Department have been engaging in a variety of other activities, such as participation in technical meetings and in the affairs of technical societies, productive sabbatical leaves, and professionally rewarding consulting work for government and industry. All these activities contribute in an important manner to our faculty being well informed about current technical developments and industrial needs, and provide the faculty with opportunities to communicate their ideas to colleagues outside M.I.T.

Professor Manson Benedict was on sabbatical leave. He spent his time preparing a second revised edition of his textbook, *Nuclear Chemical Engineering*, in collaboration with Professors Edward A. Mason of our Department, and Thomas Pigford of the University of California at

Berkeley. Professor Benedict spent about three months visiting various fuel-processing installations around the United States, gathering up-to-date information for inclusion in the new edition of this book.

Professor Irving Kaplan was also on sabbatical leave. He spent the fall term organizing the material on the history of atomic theory that he has been gathering for many years. During the spring term he offered this material as a special subject in the Department of Humanities at M.I.T.

Dr. Allan F. Henry of the Bettis Atomic Power Laboratory of Westinghouse spent the year with us as a Visiting Professor. He taught three subjects, Elementary Nuclear Physics, Advanced Reactor Physics, and Space-Time Reactor Kinetics, and he assisted in the guidance of students working on their research projects. We are happy that Dr. Henry has decided to join our Department permanently as Professor of Nuclear Engineering.

Several members of the faculty have given invited papers at international conferences. Professor Benedict attended a conference, "Problems on the Isotope Separation of Uranium," in Turin, Italy. Professor Elias P. Gyftopoulos was a U.S. delegate at the Japan-U.S. Seminar on Nuclear Reactor Noise, held in Tokyo and Kyoto, Japan. Professor Sow-Hsin Chen gave a paper at the International Conference on Statistical Mechanics, held in Kyoto, Japan.

Many members of our faculty are active members of various committees of professional societies. In particular, Professor Gordon L. Brownell was elected chairman of the Isotopes and Radiation Division, Professor Gyftopoulos was elected chairman of the Aerospace Division, Professor Theos J. Thompson was elected chairman of the Reactor Physics Division, and Professor Henry was appointed chairman of the Honors and Awards Committee, of the American Nuclear Society.

Professor Benedict received the Atomic Energy Commission citation for outstanding service in the nation's atomic energy program, the Robert C. Wilson award in Nuclear Chemical Engineering of the American Institute of Chemical Engineers, and the Arthur Holly Compton Award of the American Nuclear Society for outstanding contributions to nuclear engineering education. He has recently been appointed Institute Professor and head of the Department of Nuclear Engineering, in recognition of his outstanding and scholarly technical and scientific contributions to industry, government, and education.

There have been some personnel changes in the Department. Professor Henri Fenech resigned to accept a professorship of nuclear engineering at the University of California at Santa Barbara. There he will have the responsibility of setting up a complete program in nuclear engineering.



During the ten years in which Professor Fenech was a member of the Department he had a profound and beneficial influence on our program in reactor engineering that is greatly appreciated.

Professor David J. Rose requested a two-year leave of absence to join the Director's office at Oak Ridge National Laboratory, where he will devote his inexhaustible and creative energies to strengthening university-National Laboratory relations, and to the diversification of the Laboratory's activities into areas such as air pollution, rapid intercity transport and general urban problems. Professor Rose's outstanding contributions to our fusion option from inception to flowering, both in teaching and original research, his acute sense of humor, and his unusual humane qualities have been unique and will be missed during his absence.

Professor Thompson requested a two-year leave of absence to accept his appointment as U.S. Atomic Energy Commissioner. We all take pride in the well-deserved honor which was bestowed on Professor Thompson. Professor Thompson's contributions to the formation and growth of the Department have been invaluable. The M.I.T. Reactor, which he designed and whose operation he directed from the day of its dedication, is still one of the outstanding university research reactors in the world. As a research facility, the Reactor has provided excellent means for training a very large fraction of our graduates. Professor Thompson's devotion to his students and his extraordinary ability to challenge them to think creatively are two of the many things we will all miss while he is in Washington. Professor Thompson has made important contributions to the field of nuclear reactor safety, physics, and engineering, which have made an impact around the world. We are looking forward to his return to the Department in 1971.

Edward J. Barnett, Assistant Director for the engineering and design of the M.I.T. Reactor, has resigned to accept a position with a consulting firm. Mr. Barnett's contributions to the reactor facility and to the training of a large number of our graduates are greatly appreciated. He will continue his association with the reactor group as a consultant.

Dr. Ronald A. Blanken, a member of the research staff of our plasma group, has been appointed Assistant Professor of nuclear engineering. In addition to his activities in thermonuclear plasma research, Dr. Blanken will assist the Department by teaching subjects related to our fusion option.

Lincoln Clark Jr., Associate Director of the M.I.T. Reactor, has been appointed Director. His service during the past decade is deeply appreciated. We are fortunate that Mr. Clark's leadership will provide continuity in the operation and improvement of the reactor facility.

Dr. James W. Gosnell, Assistant Director for Operations of the M.I.T.

Reactor, has been appointed Assistant Professor of nuclear engineering. He will continue to serve as Assistant Director, and, in addition, will participate in the teaching activities of the Department.

Dr. David D. Lanning, of Battelle Northwest, has been appointed Professor of nuclear engineering. He is a former member of our faculty. His interests are in the areas of reactor experimental physics and reactor engineering. In addition to his teaching and research duties, Professor Lanning will act as chairman of a Reactor Advisory Committee. He will continue the plans for the redesign and reconstruction of the M.I.T. Reactor which Professor Thompson initiated about a year ago. We are very happy that Dr. Lanning is returning to our faculty.

Dr. Neil E. Todreas, the senior reactor engineer in the Division of Reactor Development and Technology of the U.S. Atomic Energy Commission (AEC), has been appointed Assistant Professor of nuclear engineering. His joining our faculty will strengthen our activities in the areas of nuclear reactor engineering, heat transfer, and fluid flow, which are an important part of the Department's objectives.

#### INSTRUCTION

During the year, the structure of our curriculum in the two principal departmental options (nuclear fission, and plasmas and controlled fusion) remained almost the same as in the previous year, except for two subjects introduced by Professor Henry.

In the fall term, Professor Henry taught the subject, Advanced Reactor Physics. He reviewed current methods of predicting neutron behavior in complex geometrical and material configurations and discussed a number of sophisticated mathematical procedures employed in the design of large power reactors. In the spring term, he introduced a subject on Space-Time Reactor Kinetics. In this subject he presented a number of methods used for the analysis of time-dependent reactor problems and emphasized areas needing further investigation.

Professor Thompson's Special Summer Program, Reactor Safety, was offered again in July, 1968. It was attended by 151 engineers and scientists, and during a three-week period covered both fast and thermal reactor safety problems. The offering of this Program during the past few summers has been an unqualified success and is satisfying an urgent need felt by both manufacturers and users of nuclear power reactors. Lectures were given by experts from many countries, and included Professors Benedict, Thompson, Michael J. Driscoll, and Thomas O. Ziebold of the Department.

Plans have been made for additions to the curriculum in 1969-1970. Professor Norman C. Rasmussen will teach two subjects on nuclear

physics for engineers. These subjects were offered previously by the Department of Physics at M.I.T., but beginning in September, 1969, they will be included in the Department curriculum.

Professor Driscoll will teach the subject, Fast Reactor Physics. As the technology moves towards the development of fast breeder reactors, more men knowledgeable in the peculiarities of fast reactors will be needed. Professor Driscoll's subject, with the fast reactor design subjects of our curriculum, will provide a comprehensive package for the acquisition of the necessary material.

Professor Kent F. Hansen will expand his subject, Numerical Methods of Reactor Analysis, to include more advanced numerical methods. This will increase the emphasis on the importance of numerical methods to nuclear engineering problems and will provide better preparation for those students who desire to do their doctoral thesis research work in the area of design methods.

The Department has set up five-year programs with the Departments of Civil, Electrical, and Mechanical Engineering and with the Department of Physics. Under these programs, an undergraduate may arrange his studies during his junior year, so that at the end of five years of study he will receive a Bachelor's degree in his undergraduate department and a Master's degree in nuclear engineering.

The activities of the Department in the field of economics of nuclear power are gaining momentum through the efforts of Professors Benedict and Mason. Work in this area is carried out in cooperation with the Sloan School of Management and is appealing to a large number of our students.

#### M.I.T. RESEARCH REACTOR

During the past year, the Research Reactor has continued to serve as the Department's most important research facility. At the same time, it has been used extensively as a radiation source for research by other M.I.T. departments and by New England organizations outside of M.I.T.

On July 19, 1959, following a year of flux measurements, calibration, and low power tests, the reactor began routine three-shift operation at a power level of 1 megawatt. This was raised to 2 megawatts in 1961 and to 5 in 1965, the present power level as the reactor completes ten years of relatively trouble-free service to the Institute.

As in previous years, the operating schedule has provided for startup on Monday morning with shutdown Friday evening, after 100 hours or more at power. Holidays and occasional major maintenance or modification work cut into the schedule, so that the average during the year has been about 92 hours per week. This has been accomplished through the

dedicated efforts of the reactor staff, headed, for most of the year, by Professor Thompson, Director; Mr. Clark, Associate Director and Business Manager; Mr. Barnett, Assistant Director for Engineering and Design; Dr. Gosnell, Assistant Director for Operations; and David A. Gwinn, Electronics Supervisor.

In many ways, 1968-69 has been a year of transition for the M.I.T. Reactor. While most research programs of the prior year were continuing, preparations for new programs have been actively pursued both by the Reactor staff and by the Department faculty. Facilities to accommodate new research were installed or were brought closer to completion, and a major study of a potential new design for the reactor core shows promise of providing substantially more neutrons in the beam ports without any increase in reactor power. Reactor income dropped to a new low for recent years, reflecting a tightening in the supply of research funds, but improvement is expected in this area.

Slightly higher than normal turnover was experienced among the reactor operators. When some difficulty was encountered in finding replacements, the remainder were most cooperative in adjusting schedules to cover all shifts. The licensing of operators now in training will alleviate this situation.

With regard to research projects during 1968-69, active programs have continued under the direction of the Department of Nuclear Engineering and other departments in the School of Engineering and the School of Science. More than 60 students annually are engaged in research based on the Reactor and its related experimental projects, and another 50 enroll in the several laboratory subjects that utilize the reactor. Most of these students are from the Graduate School.

Other colleges and universities continue to send materials to the Reactor for irradiation. During the past year, these have included Boston College, Boston University, Brandeis University, University of Hawaii, Wellesley College, and Woods Hole Oceanographic Institution. A total of 25 educational institutional and other research centers have used the Reactor periodically during its decade of operation. Of three hospitals and 32 industrial firms which have used the Reactor in the past, many are still regular or intermittent customers. The Reactor serves educational needs of the community by employing Northeastern University cooperative students and by other means such as providing guided tours for schools, colleges, professional organizations, civic groups, and others.

Preparations for new research received much attention from the reactor staff and Department faculty. Most of this research is described in the following section of this report.

Design studies initiated in 1968 for renovating the Reactor core were

pursued actively during the past year by a group of students and staff under the direction of Professor Thompson. After consideration of many variations, it appears that a compact core cooled and moderated by light water and surrounded by a heavy water reflector will optimize the flux in the spectrometer ports, increasing it by a factor of nearly five without any increase in reactor power. The design team has investigated various core configurations, beam port parameters, thermal column and medical port changes, and other topics in its efforts to provide the best possible reactor facilities for research investigators. After a further period of study, the necessary license approvals will be obtained and the new core fabricated. Installation is expected in the summer or fall of 1970.

A 2-inch fast flux facility in the hohlraum has proven so useful that a 6-inch facility of the same type was built and installed for researchers at the Instrumentation Laboratory, who are studying the effects of fast neutrons on the performance of electronic components and circuits.

The current emphasis on improvement and on new facilities is not unexpected. It was estimated that a substantial amount of such work would be required about ten years after startup, and a depreciation fund established for the purpose has paid for many of the past improvements and will bear the cost of the new core. We are also indebted to the Sloan Basic Research Fund, the National Science Foundation (NSF), and the M.I.T. Instrumentation Laboratory for assistance with some of the new facilities.

With regard to operating costs and revenue, the former were held to an amount very close to that of the preceding year, but limitations on research funds have resulted in a deficit of about \$95,000 for 1968-69, as indicated below. This makes the total loss during 11 years of operation \$160,000, 92 per cent of which has occurred since January, 1968.

	Eleven years 1958-69 (estimated)	1968-69 (estimated)
Receipts	\$2,880,000	\$195,000
Expenditures	3,040,000	290,000
Difference	-\$160,000	-\$95,000

Efforts to procure additional revenue have been going forward in several areas. New research projects involving reactor blanket studies, spectrometer investigations, and cryogenic irradiations, described in the following sections of this report, should more than compensate for projects now restricted or terminated because of loss of financial support. Information on the M.I.T. Reactor and its capabilities is presently being circulated to colleges and universities in the New England area. In April, 1969, through an ad hoc committee organized largely at Professor Benedict's instigation, departments of nuclear engineering across the country

submitted a report to the Federal government, describing the continued rapid growth of the nuclear industry, the contributions which universities can make, and the need for additional Federal financial support for nuclear engineering education. Two other reports, aimed at procuring additional funds specifically for reactors, are being prepared by committees representing primarily the major university research reactors. We are presently looking forward to participation in a reactor-sharing program being initiated by the AEC. If approved, this program will provide reimbursement to M.I.T. for additional use of its reactor by other colleges and universities in the area.

Although the drop in revenue indicates a reduction during 1968-69 in the utilization of neutrons by research projects at the M.I.T. Reactor, the year in general has been one of increased activity, with fully as much, if not more, participation by students, faculty and staff, and with substantial progress on new additions and improvements which will enhance the ability of the Department to continue to provide most valuable reactor facilities and services.

#### RESEARCH AT THE M.I.T. REACTOR

The M.I.T. Reactor is used for a variety of research projects by a number of M.I.T. departments, including the Departments of Chemistry, Earth and Planetary Sciences, Metallurgy, and Materials Science, Physics, and Nuclear Engineering.

The Reactor Physics Project, initiated under AEC auspices in 1968, succeeds the former M.I.T. Lattice Project. The primary objective of the new program is to perfect and apply methods for the determination of reactor lattice parameters using single or few-rod experiments. Realization of this objective would provide an extremely inexpensive way to investigate the properties of scarce or hard-to-handle fuel types, such as plutonium-recycle or partially burned assemblies.

Most of the experiments involve foil activation measurements external to single-fuel elements, immersed in D<sub>2</sub>O moderator in the M.I.T. Reactor exponential tank. During the past year experimental work has been devoted to methods development using well-understood one-inch diameter natural uranium fuel, and to applications involving clustered pressure tube-type fuel assemblies containing plutonium. A second major area in which work was carried out during the past year involved more extensive use of numerical experiments in the preliminary planning for and evaluation of the actual physical experiments. The third major phase of project work was in the application of high-resolution Ge(Li) gamma-ray spectrometry to the determination of reactor physics parameters. A spectrometer was constructed outside an M.I.T. Reactor beam-port and experi-

ments were carried out to collect prompt gamma-ray spectra during thermal neutron irradiation of fuel rods and of individual fertile and fissile species. Feasibility studies for an in-pile spectrometer were also carried out. It is hoped that, by exploitation of these more sophisticated methods, more convenient, more rapid accurate methods can be developed for the measurement and analysis of data pertinent to the neutronic characteristics of test fuel elements. Currently, arrangements are under way to obtain some spent fuel rods from the Dresden Boiling Water Reactor core, in order to permit further work on measurement of burned fuel parameters using decay gamma spectral analysis. Professors Thompson, Kaplan, Driscoll, Rasmussen, and Franklyn M. Clikeman are involved in this project. Under their supervision six students are working on doctoral thesis research programs.

The work on the construction of cryogenic test chambers operated at the normal boiling point of helium ( $4.2^{\circ}\text{K}$ ) was continued and carried almost to completion by Professors Thompson and Ziebold, Mr. Barnett, and a doctoral student. This work includes the installation at the M.I.T. Reactor of a large helium liquifier. The helium plant will refrigerate two cryogenic chambers in the M.I.T. Reactor. One of these is a materials irradiation thimble located within a fuel element in the core. The second cryostat chamber will be located in the reactor thermal column to provide a refrigerated moderator assembly.

The reactor cryogenic facilities will be made available on a general basis to all users of the M.I.T. Reactor. A variety of experiments have been suggested. Two of these are currently being initiated.

Professor Ziebold, in cooperation with Professor Ali S. Argon of the Department of Mechanical Engineering, has initiated a program to study the neutron damage defect spectrum in structural metals using the materials cryostat. The specific areas of investigation are the size distribution of induced defects (from scattering of electrons, photons, and phonons and from microscopy), the strain fields associated with induced defects (from divergent beam X-ray diffraction and stress relaxation measurements), the relation of defect structure to deformation modes (using scanning electron microscopy of irradiated tensile samples as they are stressed), the basic effect of the damage defect spectrum on plastic deformation (testing of samples with varying pre-strain and thin film microscopy), and the effects of radiation damage on fracture (studies of fracture modes under different conditions of mean stress, temperature, and strain rate). The program will be supported by the Office of Naval Research, and students will use the hot laboratory at the Naval Research Laboratory in Washington, D.C., for the metallographic examination of irradiated samples.

Research on the effects of neutron bombardment on heat transfer from heated solids to boiling helium is currently progressing under the supervision of Professor Ziebold and Professor Joseph L. Smith of the Department of Mechanical Engineering. These experiments were initiated both for the purpose of establishing design data for the in-core cryostat and for the purpose of extending basic data on boiling heat transfer. In addition, arrayed thermal sensors — small germanium patches deposited on copper — are being constructed to determine if there are local temperature fluctuations on a heated surface during the various regimes of boiling.

In the general area of radiation effects in solids, Professor Ziebold and his students are also conducting studies on the influence of 14-MeV neutrons on the dynamic elastic modulus and internal friction in high purity copper. The immediate interest is to see whether or not there is a basic difference between the effects caused by 14-MeV neutron bombardment and those caused by reactor neutrons. High-energy neutrons are obtained from the Department's Cockroft-Walton accelerator. This investigation is interesting both in its own right, and in feasibility studies of controlled nuclear fusion systems. In such systems, it is anticipated that flux rates  $10^{14}$ – $10^{15}\text{cm}^{-2}\text{sec}^{-1}$  of pure 14-MeV neutrons will be impinging on the vacuum wall of the device, and that the total integrated flux will be  $10^{22}$ – $10^{23}\text{cm}^{-2}$ . Radiation damage by 14-MeV neutrons at such levels is presently impossible to create, but studies at much lower levels should yield useful information.

Professors Driscoll and Thompson and their students completed the construction of a converter facility for the M.I.T. Reactor thermal column, capable of simulating accurately the fast neutron spectrum prevalent in a fast breeder reactor, and suitable for simulation and investigation of fast reactor blankets. By December, 1968, all internal components and external shielding had been fabricated and installed. During the spring term, construction and testing of carts that support the low enrichment uranium converter assembly and the blanket assembly were completed. This facility was financed by a \$25,000 allocation from the M.I.T. Reactor renovation funds. A research program has been approved by the AEC to support a series of experiments designed to collect basic data and to permit experimental optimization of breeding blanket design.

Professors Driscoll, Thompson, and Clikeman and their students continued experimental work on fast spectrum neutron interactions. An experimental converter assembly designed to provide a pure fission neutron and gamma spectrum was designed, constructed, and installed in the hohlraum of the M.I.T. Reactor thermal column. This facility is now being used by M.I.T. Instrumentation Laboratory researchers to study



fast neutron damage in semiconductor components of electronic circuits. A second and smaller but similar unit was installed previously to produce N-16 activity in  $H_2O$ . This facility continues to be operated as a small departmental program for the study of nitrogen radiochemistry.

Recent establishment of a neutron spectrometry capability, using a Sloan Fund allocation, has materially strengthened and coordinated our experimental program in this whole area.

Professor Brownell and an associate from the Massachusetts General Hospital continued their studies regarding the use of the M.I.T. Reactor for neutron capture therapy. The principal aim of the work is the development of an epithermal beam to provide improved thermal neutron depth distribution. Experimental studies have also dealt with improved methods of dosimetry of the mixed beam appearing at the medical therapy facility. Recoil spectra from which fast neutron dose is determined are observed with a silicon semiconductor detector. Other methods of dosimetry include tissue equivalent ionization chambers and semiconductor degradation techniques. The program is sponsored by the National Institutes of Health (NIH) and the Atomic Energy Commission.

Professor Rasmussen and his students continued their work in high-resolution gamma-ray spectroscopy. The early work was done with bent quartz crystal spectrometers and a scintillation triple coincidence pair spectrometer. During recent years, most of the effort has been spent in the development and use of high-resolution lithium-drifted germanium solid-state gamma-ray detectors. Using techniques similar to those developed originally at the Chalk River Laboratory, counters have been produced with active volumes as large as  $40\text{ cm}^3$ . These new detectors have been used for the nondestructive analysis of spent reactor fuel, neutron gamma-ray studies, and work in prompt activation analysis. In addition, detectors have been supplied to a number of other laboratories at M.I.T. The detectors have been used to determine the capture gamma-ray spectra of some 75 elements. This compilation has recently been published. Currently the data is being reanalyzed to determine the total gamma-ray yield as a function of energy. For shielding calculations, the data need to be analyzed both in the resolved peaks and in the unresolved part of the spectrum. Considerable work has also been carried out on the development of a computer code for the analysis of complex spectra. The method developed employs Fourier transforms. It is currently being used at several other laboratories.

Professor Brownell and an associate from the Massachusetts General Hospital are using thermal neutron activation analysis in conjunction with solid-state detectors to study the role of trace elements in blood and tissues of experimental animals and man and their relationship to the

incidence and progression of various diseases. Further, studies are in progress on the role of trace elements in the action of certain biochemical substances such as RNA. The program is sponsored by NIH.

Professor Chen and a student are engaged in the construction of two neutron spectrometers in front of a 12-inch beam port. One is a new version of a three-axis spectrometer which uses a double-crystal monochromator to obtain an exceptionally clean monochromatic neutron beam. It is particularly suited for the investigation of elementary excitations, such as phonons and magnons in metallic and molecular solids. The other spectrometer is a time-of-flight machine which makes use of the method of correlation chopping. It is suited for detailed studies of collective and diffusive atomic motions in simple liquids and liquid metals. The project is funded by the Sloan Fund for Basic Research and by the AEC. The theoretical aspects of the program are studied jointly by Professors Sidney Yip and Chen.

#### RESEARCH WITH THE ROCKEFELLER GENERATOR

Next to the M.I.T. Reactor, the 3.5-MeV Rockefeller van de Graaff Accelerator is probably the Department's most versatile experimental facility. It is currently being used for measurements of fast neutron inelastic scattering cross sections, neutron slowing down studies, and measurements of capture gamma-ray spectra from resonant energy neutrons. The work is being carried out under the supervision of Dr. Leon E. Beghian and Professor Clikeman, and it is sponsored by NSF.

In this program the gamma-ray de-excitation spectra of nuclei which have been excited by fast neutrons are measured. The measurement of the de-excitation gamma-ray spectra as a function of neutron energy allows the determination of neutron-induced gamma excitation functions. This information, together with gamma-ray energies from the spectra, yields the energies of nuclear energy levels. Gamma-ray excitation functions, together with theoretical calculations, allow the addition of the proper spin and parity to the structure of nuclear level, thus resulting in a relatively complete picture of the structure of nuclear levels.

Professors Clikeman and Yip and their students are using the Rockefeller generator to study the slowing down process of fast neutrons in various absorbing materials. The experimental results are being correlated with theoretical calculations which are concurrently carried out.

#### REACTOR CALCULATIONS

Professors Driscoll, Kaplan, and Thompson and their students have continued their work on the development of theoretical methods for the analysis of fast reactors. First, work was completed on a phase of the

modal analysis techniques which have been under investigation for the past five years. This work showed that the use of as few as two overlapping neutron-energy spectra could provide accuracy comparable to that achieved in many-group calculations of the conventional multigroup type. Equally important, a way to estimate and bound the error involved in modal approximations was developed, and the numerical problems involved in solving the spatial part of the modal method were clearly defined for the first time. Future work now under consideration includes applications of the modal analysis techniques to burnup and to multi-dimensional flux shape calculations. Second, methods have been developed for the calculation of inelastic scattering matrices for multigroup cross section sets which permit an alternate description to statistical theory for the energy region in which cross sections have overlapping resonances. Finally, work has been initiated in two important areas: the calculation of core and blanket breeding and burnup performance, and reactivity accident analysis of liquid metal fast breeder reactors. Three doctoral theses have been started on these topics. They will provide the focal point for a continuing effort in this area during the next several years.

Professor Gyftopoulos and one of his students completed work on the application of dimensional analysis methods to the excursion behavior of reactors. The methods may be used to correlate available excursion data or to obtain a correlation from a few computer calculations. Two sets of correlations have been obtained. The first pertains to data from eight plate-type cores of the SPERT (Special Power Excursion Reactor Tests) program. The correlations are in the form of a product of powers of the dimensionless parameters which characterize the reactor. The correlated data have a total scatter band for all eight cores of the same order as the scatter band in the correlated data from an individual core. In developing these correlations, it was found important to include the feedback effect due to spectral hardening, an effect that was neglected in previous analyses of SPERT data. The second set of correlations pertains to the oxide rod-type cores and is based upon the results of two cases calculated, using the PARET digital computer code. It is shown to give quite reasonable agreement with the results of 12 other cores as calculated using PARET and with experimental results for two SPERT, oxide rod-type cores.

Professors Hansen, Henry, and Gyftopoulos and their students have pursued very actively their research in numerical methods for the analysis of spatially dependent reactor dynamics, under AEC sponsorship. Several approaches to the problem are under study. An alternative approach using fractional step methods has been modified to suit the particular needs of dynamic problems. The usual forms of fractional step methods

are stable for the kinetics equations, but have very large truncation error. Recent developments led to a considerable reduction in the error. Further, rather general conditions for stability for fractional step methods have been proven.

Finally, a very interesting study in fast reactor dynamics has been started. In static calculations it is possible to reduce a multigroup set to a few-group set while preserving reaction rates and criticality. The weighting spectrum used is the critical multigroup spectrum. In a transient situation the spectrum changes, and this gives rise to small changes in the few-group constants. Sample calculations have shown that very small spectrum perturbations give rise to very large differences in the transient response of the system. This is a very interesting result, for it suggests that the calculations for fast reactors may require a many-group model with a consequent increase in complexity. Further study of the problem is now under way.

#### FUEL CYCLE STUDIES AND ECONOMICS

Under the leadership of Professors Benedict and Mason, the Department is active in work concerned with the development of techniques for the calculation of long-term reactivity changes in nuclear reactors, fuel burn-up and composition changes, fuel value, and the techniques and economics of fuel management.

The effect of U-236 and Np-237 on the value of uranium as feed for various thermal power reactors has been investigated using computer codes. The cost penalty for the presence of U-236 in reactor feed was determined for a range of economic conditions; the penalty, or \$/gram of U-236, is strongly dependent on the price, or value, assigned to Np-237 (as a feed for the production of Pu-238, a valuable energy source for radioisotopic power). The indifference price for Np-237 was found to lie between about \$34/gm and \$60/gm for all the economic inputs considered; thus, if Np-237 has a value of less than \$34/gm, the presence of U-236 in reactor feed is detrimental and increases net energy costs, whereas if Np-237 has a value greater than \$60/gm, the presence of U-236 in fuel fed to the reactor is beneficial and results in lower energy costs. The value of plutonium in a mixed system of thermal and fast reactors has also been studied.

In another study, Professor Benedict and a student investigated the characteristics of the uranium enrichment industry. The effect of different charges for enriching uranium on the amount of separative work which would be purchased by light water reactors now committed was determined, and estimates were made of the impact of changes in the price of separative work on the rate at which new nuclear power plants would

be built in competition with other types. It was found that the demand for separative work was relatively inelastic, so that owners of diffusion plants could increase gross revenue by raising prices.

Professor Mason and his students have initiated research on economic analyses of large nuclear energy centers coupled with industrial and agricultural production complexes. The relationship between the major factors affecting the optimum size of nuclear power stations will be studied. An economist on the faculty of the Sloan School of Management is cooperating, and it is hoped that such ties with the Sloan School and also with the Department of Economics can be increased and improved. The advantages of multireactor power stations are under study, considering possible savings in capital, operating, and fueling costs and transmission costs. The relationships between total operating costs and flexibility of supplying a variable demand for desalted water and electricity by a dual-purpose nuclear station are also being investigated.

#### HEAT TRANSFER RESEARCH

Professors Fenech and Mason, in cooperation with Professors Warren M. Rohsenow and Arthur E. Bergles of the Department of Mechanical Engineering and several graduate students, are investigating various phenomena in the areas of heat transfer and fluid flow. An experimental program on two-phase flow is in progress. Measurements have been completed on flow of air-water mixtures in the annular flow regime, which gives the amount of dispersed liquid at several liquid and air flow rates. An experiment is in progress to determine the effect of the liquid surface tension and viscosity on these phenomena.

Other experiments with water droplets in air flow have been completed. For droplet diameters within an order of magnitude of 100 microns, it has been found that the mean free path to the wall of dispersed and accelerated droplets is roughly proportional to droplet diameter. After assuming a drop-size spectrum and a magnitude of entrainment, analytical expressions for deposition, dispersed flow rate, mass transfer coefficient, mean diameter and spectrum shifting down stream have been derived.

Another project is concerned with the experimental investigation and the analytical description of the basic phenomena leading to two-phase flow oscillations in boiling channels subjected to a constant pressure drop from inlet to exit. A carefully instrumented freon-113 experimental loop, having three electrically heated glass boiler tubes in parallel with a large bypass, is used to obtain the experimental data.

Finally, an experimental study of the effectiveness of using surface promoters as a means of augmenting heat transfer from rectangular channels of high aspect ratio was completed. Heat transfer coefficients,

from both smooth and internally finned channels to water flowing through the channels, were measured. Power density and coolant flow rate were varied over a range designed to bracket the conditions expected to exist in the proposed high-flux M.I.T. Reactor.

#### APPLIED PLASMA PHYSICS STUDIES

During the past year, Professor Rose, in close collaboration with Oak Ridge National Laboratory, completed an extensive feasibility study of a controlled fusion power reactor. The study assumes that adequate plasma confinement can be achieved, a point which is still under intensive investigation by the majority of plasmologists. Nevertheless, given quasi-equilibrium plasma conditions and assumptions about confinement, the question which concerns how such a device might be built is examined. It seems fairly clear that (given the assumptions): (1) a very large neutron excess would exist in a fusion reactor, allowing both tritium to be bred for the fusion reaction and a substantial excess for other purposes; (2) niobium and molybdenum alloys are the desired structural materials; (3) a total power load of 10 megawatts/meter<sup>2</sup> of vacuum wall facing the fusion plasma can be achieved, and perhaps more; (4) unit size will be very large — 2,000 to 10,000 megawatts [electric]; (5) the unit cost per kilowatt would be very low; (6) there are very substantial siting advantages [chiefly due to negligible hazard]; (7) tritium fuel handling is probably not a problem; (8) if the laws of plasma physics assumed to be operating in present small laboratory devices remain valid in large devices, plasma confinement may not be as serious as many suspect. These conclusions are obviously tentative, but serve to outline the maneuvering space for fusion. The study continues on many fronts: radiation damage to structural materials under expected fusion reactor conditions, development of yet more efficient vacuum walls capable of giving high heat transfer, economic and technical studies of fission-fusion combinations.

Professor Lawrence M. Lidsky and one of his students completed a preliminary design study of a 14-MeV D-T intense neutron source with surface density 10<sup>14</sup>/cm<sup>2</sup>, using a windowless gaseous target. The target is the sonic line of a Mach-8 hypersonic tunnel with 32 g/sec mass flow and 1 torr ambient pressure. Operating such a tunnel would require approximately 1 Mw of electrical power. The device could be used for studies of radiation damage in a fusion reactor system or, by suitable blanketing, as a high intensity, moderately high energy neutron source for making up breeder reactor spectra.

Professor Lidsky and his students are studying experimentally a number of plasma phenomena, such as wave-particle scattering, cyclotron frequency instabilities in beam-generated plasmas, unstable plasma waves,

anomalous diffusion, turbulence and plasma diagnostic techniques by means of Thomson scattering. In addition, they are measuring electronic and ionic scattering cross sections in the intermediate energy range of 100-1,000 eV.

Professor Thomas H. Dupree and his students continued their theoretical investigations of unstable plasma states by considering the effects of fluctuations on plasma confinement, heating and radiation.

#### OTHER RESEARCH ACTIVITIES

Professor Yip and his students have developed new theoretical models for the description of thermal fluctuations in gases and liquids, and for the calculation of transport coefficients. The results are in good agreement with observations.

Professor Yip and one student are carrying out a detailed study of intermolecular forces in a number of molecular solids. Normal mode calculations have been performed for the sodium azide ( $\text{NaN}_3$ ) crystal.

Professor Chen and one student have developed a technique for the performance of photon intensity correlation measurements. The technique is particularly useful for the study of slow density or concentration fluctuations near the critical points and the diffusive motion of macromolecules in solution.

Professor Gyftopoulos, in cooperation with Dr. George N. Hatsopoulos, has completed work on the implications of the second law of thermodynamics in quantum theory. The essence of this work was the development of a physical theory consistent with both the laws of quantum mechanics and the second law of thermodynamics. Many far-reaching conclusions have been reached of import both to quantum theory and to the relation between mechanics and thermodynamics. The results are consistent with experience, but contrary to a large number of opinions prevailing in the literature. For example, the ergodic hypothesis is shown to be meaningless, all existing expressions for entropy are shown to violate the laws of quantum mechanics, and irreversibility is attributed to the "vacuum" of relativistic quantum field theory. The theory is applicable to all systems, all states, and all processes.

Professors Mason and Hansen and a student are continuing their analyses of solid-core nuclear rockets. The analyses are directed at investigating the effects of nonuniform uranium loading, nonuniform coolant channel distribution, coolant passage dimensions, materials properties, and heat transfer on limiting rocket performance.

Professor Mason and another student completed their work on the application of radioisotopes and subliming materials for attitude control and a passive means of fast stabilization of an M.I.T. Sunblazer type solar

probe. This is accomplished by an "erecting" shell and a few pairs of despin microthrusters. The erecting shell is a cylindrical metallic shell coated with subliming material which generates the "erecting" force as a result of asymmetry of the temperature distribution due to thermal lag in heating by absorption of solar radiation. The despin microthruster serves the purpose of providing a large despin torque initially and a lower despin torque constantly for the rest of the mission by alpha particle emission. The microthruster consists of a conic cup filled with a subliming material doped with radioisotopes and the bottom of the cup contains a layer of an alpha-emitting radioisotope.

Professors Benedict and Mason and their students performed an engineering evaluation of the use of chemically generated reflux in the ammonia-hydrogen exchange process for hydrogen-deuterium separation. Reflux to the exchange tower would be provided by cracking deuterium-enriched ammonia to hydrogen and nitrogen at one end of the exchange process and recombining hydrogen and nitrogen into ammonia at the other. Unit, capital, and operating costs for the process have been estimated.

#### **CONCLUSIONS**

The foregoing brief descriptions of the projects of our faculty and students are indicative of the interdisciplinary approach the Department takes in attacking the problems of nuclear engineering education and in advancing knowledge related to nuclear energy. We believe that this approach provides our students with the opportunity to integrate their undergraduate training, and with the intellectual attitude necessary for professional work in an environment of changing technology.

ELIAS P. GYFTOPOULOS

#### **CENTER FOR ADVANCED ENGINEERING STUDY**

The activities of the Center continue to grow in scope and size. The new building of the Center, with its faculty offices, study offices for participants in the Center's programs, seminar and classrooms, a 170-seat lecture hall, a high-speed digital computer laboratory, and a completely equipped television tape production facility, has significantly contributed to our capabilities.

#### **THE PRACTICING ENGINEER ADVANCED STUDY PROGRAM**

The Practicing Engineer Advanced Study Program is designed for men who have supplied and will continue to provide the initiative, leadership,



and accomplishment that catalyze technical progress. The Program provides an opportunity for such people to spend one or more academic terms participating in any academic, research, or other M.I.T. activities that are relevant to their present and future needs. The purpose of sending a man to the Center is to prepare him for future responsibilities in his home organization. Because each man's program is individually tailored, the Center is able to prepare men for future roles that encompass:

1. Technical management. The individual's program combines work in key technical fields with work in relevant management areas.
2. Creative leadership in an area that demands the application of knowledge from several disciplines. The individual's program is designed to add new fields to his current background.
3. In-depth accomplishment in one discipline. The individual's program is tailored to lead to capability to extend the frontier of a discipline.

In the past five years, 92 men have completed this program. Their median age has been 39. The majority of the participants have been employees of industrial firms, but agencies of the Federal and local government and sister universities have also sponsored Fellows. The formal educational backgrounds of the Fellows in the program have encompassed aeronautical engineering, applied mathematics, chemistry, chemical engineering, civil engineering, electrical engineering, mechanical engineering, metallurgy, and physics. The study programs followed are tailored to meet the objectives of the individual and his sponsoring organization. No two individuals follow identical programs. Each program is designed, in the light of the background and future plans of the Fellow, as an optimum experience. This flexibility is achieved by drawing on all of the educational resources of M.I.T. and, in cases where greater scope is indicated, arrangements are made to include work at other educational and research activities in the metropolitan Boston area. No constraints are placed on the areas pursued. A Fellow is not restricted by disciplinary bounds, but is encouraged to work at any level in any discipline that is commensurate with his background and objectives. The program of a Fellow of the Center often combines very advanced work in one area with studies at a basic level in another. Some participants carry a substantial load of formal classroom subjects; some work out, with the help of interested faculty, guided special study activities; some dig deeply into research frontiers. The nucleus of the majority of the programs followed by the Fellows is built around the special subjects designed and offered by the Center to meet the needs of the mature professional.

The contributions that the Fellows of this Program have made upon

their return to their sponsoring organizations continue to demonstrate the validity of the Program.

#### **THE PROGRAM IN SYSTEMATIC POLICY ANALYSIS**

In 1967-1968 the Center, in cooperation with the Department of Political Science, initiated a new, full-year academic program in systematic policy analysis. The Program was also offered in 1968-1969, with 16 Fellows in residence.

The program is designed to provide mid-career officials of Federal, state, and local government agencies with the capability to apply modern systems technology developments to the selection, organization, management, and operation of large public programs.

The Program emphasizes the application of economic analysis, operations research, and other quantitative methods to problems of public policy and management. As in the Practicing Engineer Advanced Study Program, the Program is flexible and tailored to the background of the individual. However, a majority of the Fellows build their program around the special set of systems analysis subjects developed and offered by the Center to members of either the Practicing Engineer Advanced Study Program or the Systematic Policy Analysis Program.

#### **SHORT INTENSIVE PROGRAMS**

During the summer of 1968, the Center offered three short intensive Programs: Engineering Systems Analysis, Field Effect Devices, and Experimental Solid-State Physics. The Programs combined participants from industry and government and faculty participants from sister institutions.

The two-week Engineering Systems Analysis Program presented the new techniques of analysis, and evaluation of large-scale engineering designs. The exposition of the material consisted of a presentation of theoretical concepts and methods by Department of Civil Engineering faculty and staff. Computer-aided problem solving developed skills in specific techniques. Large-scale applications developed insight into how these procedures can best be combined.

Thirty-nine participants attended the Program. Twenty-three of these were faculty members from 19 colleges and universities in the United States and Canada.

The three-week Field Effect Devices Program was presented by faculty members of the Department of Electrical Engineering and guest lecturers. Nineteen participants attended the Program. Seven were faculty members from other institutions.

The Program presented a concentrated treatment of junction and metal

oxide semiconductor field effect devices, including the physical electronics, fabrication techniques, circuit design and state-of-the-art applications. The participants became knowledgeable in the use of the field effect transistor as a circuit element.

The five-week Program on Experimental Solid-State Physics was taught by faculty from the Departments of Electrical Engineering and of Metallurgy and Materials Science.

The main feature of the Program was the experimental work in the laboratory. Fifteen experimental projects were available and suggestions as to the nature of possible experiments were made to the participants.

Eighteen participants attended the Program. Fourteen of these came from colleges and universities.

In the spring of 1969, the Department of Civil Engineering, in cooperation with the Center for Advanced Engineering Study, offered a three-day seminar on Seismic Design for Nuclear Power Plants. Presentations by the Departments of Civil Engineering, of Earth and Planetary Sciences, and of Nuclear Engineering faculty and guest lecturers reflected the problems encountered in the several professions concerned with the design of nuclear power facilities. The purpose of the seminar was to put in perspective the nature of the problem, its importance, the present design process, current difficulties, and newer solutions. The emphasis was on the seismic design problem in the eastern two-thirds of the United States, where the seismic threat is less well defined. Another purpose of the seminar was to present the newer technical methods, some still under development, for treating the various design problems.

One hundred and seven participants attended.

#### **COOPERATION WITH THE URBAN SYSTEMS LABORATORY**

The Center and the Urban Systems Laboratory are cooperating in the development of a program in the urban area. This program will offer working professionals from industry and government the opportunity to add to their current background those skills, insights, and approaches relevant to tackling problems in the urban scene. The program will deal with the manner in which technological, political, economic, and business expertise can be combined to contribute to the solution of urban problems.

#### **ON-THE-JOB CONTINUED EDUCATION**

The program of development of subjects for home study by working professionals has continued. Texts, films, and problem solutions for two subjects, Probability Theory, and Random Processes, have been com-

pleted and tested. Release to industry is scheduled for the spring of 1970. Other subjects will follow.

HAROLD S. MICKLEY

### **PROJECT INTREX**

Now in its fourth year of operation, Project INTREX (INformation TRansfer EXperiments) continues to be guided by its original goals of finding long-term solutions for the operational problems of large libraries and of developing competence in the emerging field of information transfer engineering. In formulating the plans for Project INTREX, M.I.T. decided to pursue the experimental program within the normal academic environment rather than establishing a special activity outside the regular university structure. The Electronic Systems Laboratory (E.S.L.), under the direction of Professor J. Francis Reintjes, took on the task of conducting experimental programs in the computer handling of catalog data and in the remote display of full text. This course of action has permitted faculty and students to participate directly with the research staff in the Project. Several theses, both graduate and undergraduate, have resulted from student involvement in INTREX. Such student participation will greatly help the dissemination of INTREX results to other universities and to industry and government.

Indicative of the Project's progress during this past year was the decision by the National Science Foundation (NSF) and the Council on Library Resources, Inc. (C.L.R.) to continue their support of the project. Under the joint sponsorship of NSF and C.L.R., the first stage of the augmented-catalog experiments was completed. Virtually all of the 10,000 documents in the initial data base have been cataloged. Initial storage and retrieval programs as well as user aids have been completed and checked out. The augmented-catalog console will be available for user experiments beginning in the summer of 1969.

A two-week conference at the Technical University of Berlin in July, 1968, provided an opportunity to demonstrate a rudimentary version of the augmented catalog. Queries originated at the Conference were transmitted by telephone communication links to M.I.T. Real-time responses of the augmented catalog were returned to Berlin over the same links. In August a paper on Project INTREX was presented at the 1968 Congress of the International Federation for Information Processing at Edinburgh.

Under the sponsorship of C.L.R., the text-access system has been readied for experimental use. The central storage unit, which houses the full text of the documents on microfiche, has been checked out along

#### PROJECT INTREX

with the transmission subsystem. Work has been completed on the two original terminals, the storage tube and the 35-mm camera-processor, as well as on an additional terminal, an Addressograph Multigraph Model 3000 electrostatic copier. The text-access system will be available for user experiments in the summer of 1969.

Renovation of the Engineering Library, which will be the environment for INTREX experiments, continued through the year. Work was completed on the fourth floor and the ring-shaped areas on the fifth, sixth, seventh, and eighth floors. The renovation of the central dome area has been started. It is expected that the work will be completed and the library fully operational during the fall term.

CARL F. J. OVERHAGE



## SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

The year 1968-69 has made it plain, if it was not already so, that M.I.T. has begun to share in the ferment common to most of the campuses of the nation. The issues are many and diverse, ranging from the character and quality of our society to the role and structure of our colleges and universities. Much of the discussion here has been on an Institute-wide basis, especially with regard to such topics of particular relevance for M.I.T. as military-related research. At the same time, a great deal of discussion has taken place within individual departments, especially that dealing with curriculum and organizational matters.

Our own School of Humanities and Social Science has special responsibilities in the face of the new mood of a more critical questioning of some of our most fundamental economic and social institutions. This has already led to the introduction of new subjects and the modifications of old ones, not only in the social science departments but in several areas of the humanities as well. This trend is very likely to be strengthened in the future.

The role of students in policy-making at the departmental level is also in an interesting state of flux. So far there have not been any radical changes in the formal decision-making machinery of our several departments; however, significant new contributions to the shaping of department policy are being made by reinvigorated student-faculty committees at both the undergraduate and graduate levels. Another innovation is the participation of students in the meetings of the Visiting Committees of several departments.

As mentioned also in last year's report, the question whether mathematics and science requirements should continue to be the same for under-

graduates in our School as in the Schools of Science and Engineering remains under discussion. The sentiment for change is still strong with some students, but it does not seem to have increased appreciably. Another issue discussed in last year's report has since been satisfactorily resolved: the elective subjects in the upper-class humanities and social science programs were all increased by a faculty vote from eight to nine units.

Other new developments being urged by some members of our School, which may or may not come to fruition in the next academic year, include: (1) separate departmental status for what is now the Philosophy Section of the Department of Humanities, (2) a new undergraduate major in Foreign Literature, combined with a secondary major in a particular field of science or engineering, analogous to our long-standing majors in Humanities, and (3) a formalizing, perhaps in the form of a new optional Humanities major, of a new type of interdisciplinary studies designated by their proponents as Social Inquiry.

Before giving way to the reports of the departments in the School, let me conclude with a now traditional summary of some of our enrollment figures.

#### GROWTH STATISTICS

The considerable expansion in almost all of the School's instructional programs over the past decade has been quite remarkable, especially at the undergraduate level where total Institute growth has been modest. The central motif of our continued expansion during the past year is that it has been largely concentrated in the Department of Humanities. This applies both to our extensive program of general education for the M.I.T. undergraduate body as a whole, and also to the smaller domain of the School's own undergraduate majors.

It is becoming more and more commonplace each year that our total registrations in undergraduate subjects, as summarized in Table I, set a new record. This year's grand total of 12,817 exceeds last year's by 566, or by a bit less than five per cent. This compares with about a 2.5 per cent increase in the total undergraduate population at M.I.T. Since enrollments in our freshman and sophomore programs increased by only 160, it may be seen that much the greater part of the increase was in subjects of junior and senior grade.

In the sophomore year, students have a choice between philosophy and literature in one semester and between several subjects in history and one in social science in the other semester. There has been a strong trend in the past few years toward history and philosophy, and this continued last year as well. Indeed, philosophy (plus 142) pulled ahead of literature



(minus 62) for the first time. History (plus 78) widened ever more its large lead over social science (minus 65).

Junior and senior electives which satisfy humanities and social science requirements fall into 11 fields. Seven of these are in the humanities, including two — foreign literature and visual arts — which are administered by other than the Department of Humanities; the remaining four fields are in the social sciences. Until last year, the aggregate social science registration had always exceeded that in the humanities. This year, even though the social sciences have continued to increase somewhat in absolute numbers, they have again lost ground relatively, falling from 48.9 per cent to 46.9 per cent.

Of the individual fields, the biggest gainer by far is the relatively new collection of "interdisciplinary subjects" (plus 312). First appearing only in 1966-67, this field is now the third largest, having jumped from sixth place last year. The second largest growth was recorded by history (plus 217), which barely nosed out political science for fourth place. Political science itself actually gained 103 enrollments, but fell in relative position nevertheless. The relative ranking of all 11 fields may be seen most clearly in Table II.

Another large gainer was psychology (plus 129), which thereby widened its lead over second-place economics to a greater margin than ever before. Economics was the biggest loser (minus 138), falling to an unprecedentedly low 15.3 per cent. Another loser was literature (minus 68), which fell from third place to sixth.

Visual arts, philosophy, and music all had relatively static enrollments. Foreign literatures and labor relations, at the bottom of Table II, both declined.

The recent history of the enrollments of majors in our School is shown in Table III. As compared with five years ago, when economics and political science majors were last combined under the heading of social science, the numbers of those majors have more than doubled. Over the past two years, however, the rate of increase has been quite modest.

Majors in humanities, on the other hand, have expanded considerably in the past two years — from 121 in 1966-67 to a record 195 in 1968-69. This also makes majors in the humanities again more numerous than in the social sciences. This traditional relationship had been reversed during the previous two years.

The total of 358 undergraduate majors in our School is also a record. This represents an unprecedentedly high 12.7 per cent of all undergraduates who had designated majors.

Enrollments of graduate students in our School, on the other hand, have merely recovered to the level first reached in 1966-67. This is a

favorable performance in the face of the draft uncertainties that have lowered graduate enrollments in the Institute as a whole. Over the longer range, the numbers of graduate students in our School have also expanded at a faster rate than in the rest of M.I.T.

Tables IV and V show that the humanities and social science elective fields are not randomly selected by undergraduates from the five various Schools of the Institute. As compared with last year, Table V shows that students in architecture have continued to moderate somewhat more their strong preference for their own department's field of visual arts, in favor of an increased selection of social science. We also see an especially clear illustration this year of a traditional pattern: students in the School of Science and in the School of Humanities and Social Science elect humanities over social science in almost exactly the same ratio (.55 to .37) that students in the School of Engineering and in the School of Management exhibit the opposite preference. This represents a return to orthodoxy as compared with last year, when science and humanities students showed less strong preferences for humanities electives and management students actually reversed their traditional preference for social science electives.

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

**Table I Registration in Humanities, Languages, and Social Science Undergraduate Subjects 1968-69.**

	Fall	Spring
Freshman program	982 <sup>1</sup>	989 <sup>1</sup>
Sophomore program		
Literature	271 <sup>2</sup>	178 <sup>2</sup>
Philosophy	332	230
History	349 <sup>3</sup>	477 <sup>3</sup>
Social science	156	100
History	352	484
Philosophy	190	361
Literature	349	317
Music	241	270
Interdisciplinary	566	327
<b>Total humanities electives</b>	<b>1,698</b>	<b>1,759</b>
Economics	550 <sup>4</sup>	661 <sup>4</sup>
Political science	375	456
Labor relations	68	67
Psychology	721	823
<b>Total social science electives</b>	<b>1,714</b>	<b>2,007</b>
Foreign literature <sup>5</sup>	105 <sup>5</sup>	98 <sup>5</sup>
Visual arts <sup>7</sup>	309	248
Thesis		
Economics	6	37
Political science	4	18
Course XXI	24	35
	34	90
English composition	14	
Senior seminar (XXI)	31	
Science writing	4	12
Elementary, intermediate, and advanced foreign languages	277	353
<b>Grand total</b>	<b>6,276</b>	<b>6,541</b>

<sup>1</sup> Includes registration in special humanities subjects in French (fall, 25; spring, 23) and in German (spring, 17).

<sup>2</sup> Includes registration in comparable subjects in French (spring, 12); and in German (fall, 9).

<sup>3</sup> Includes registration in comparable subjects in French (fall, 23); and in German (spring, 10).

<sup>4</sup> Includes registration in Economic Principles I, 14.01 (fall, 295; spring, 337).

<sup>5</sup> Exclusive of 630 registrants in elementary, intermediate, and advanced languages.

<sup>6</sup> Includes undergraduates in graduate linguistic subjects (fall, 16; spring, 3).

<sup>7</sup> Taught by faculty of the School of Architecture and Planning.

Table II Percentage Distribution of Junior and Senior Electives in Humanities, Languages, and Social Science, by fields, 1962-69.\*

	1968-69	1967-68	1966-67	1965-66	1964-65	1963-64	1962-63
Psychology	19.5	19.0	18.1	16.6	20.2	21.4	14.8
Economics	15.3	18.1	21.9	22.8	19.9	19.7	24.8
Interdisciplinary subjects	11.2	7.8	5.2				
History	10.5	8.3	9.1	10.2	8.5	5.6	5.9
Political science	10.5	9.8	9.6	9.2	9.3	10.4	10.5
Literature	8.4	9.8	11.1	12.7	12.5	12.5	14.4
Visual arts <sup>1</sup>	7.0	7.3	6.7	6.4	4.8	3.1	2.8
Philosophy	6.9	7.5	6.9	9.3	9.1	13.2	12.0
Music	6.4	7.1	7.2	7.7	8.9	8.2	7.8
Foreign literature <sup>2</sup>	2.6	3.2	1.9	2.7	4.3	3.5	4.0
Labor relations	1.7	2.1	2.0	1.9	2.1	2.3	3.0

\* Omitting registrations in the Freshman and Sophomore programs and in the miscellaneous fields following Visual Arts in Table I.

<sup>1</sup> Taught by faculty of the School of Architecture and Planning.<sup>2</sup> Exclusive of elementary, intermediate, and advanced language subjects; includes undergraduates in graduate linguistics subjects.

Table III Majors in the School of Humanities and Social Science\*

	Undergraduates						Graduates					
	Social Science	Humanities	Total	Social Science	Humanities Literatures	Foreign Literatures	Social Science	Humanities Literatures	Foreign Literatures	Total	Grand Total	
1955-56 <sup>1</sup>	40	19	59	52	—	—	52	—	—	—	52	111
1956-57	38	32	70	69	—	—	69	—	—	—	69	139
1957-58	41	67	108	74	—	—	74	—	—	—	75	183
1958-59 <sup>2</sup>	46	75	121	81	—	—	81	—	—	—	82	203
1959-60	38	64	102	105	—	—	105	—	—	—	107	209
1960-61	35	93	128	114	—	—	114	—	—	—	114	242
1961-62 <sup>4</sup>	55	88	143	129	—	—	129	—	7	—	136	279
1962-63 <sup>5</sup>	65	85	150	145	—	—	145	—	22	—	167	317
1963-64	71	87	158	165	—	—	165	—	4	—	200	358
1964-65 <sup>6</sup>	78	109	187	190	—	—	190	—	15	—	241	428

	Political Science			Political Science		
	Economics	Political Science	Total	Economics	Political Science	Total
1965-66	50	60	114	111	63	23
1966-67	76	73	121	117	79	26
1967-68	81	76	148	114	80	27
1968-69	84	79	195	118	87	27

\* As registered in the second term of academic year 1955-56 to 1968-69 (omitting freshmen)

<sup>1</sup> Course XXI initiated.<sup>2</sup> Graduate degree in political science initiated.<sup>3</sup> Special program in teacher training.<sup>4</sup> Graduate degree in linguistics initiated.<sup>5</sup> Graduate degree in psychology initiated.<sup>6</sup> Graduate degree in philosophy initiated, with small preregistration in 1963-64.

Table IV Distribution of Registrants in Undergraduate Electives by Schools and Fields (by numbers), 1969-70.

School	Subtotal in the										Subtotal in the Humanities	Grand Total		
	Economics	Labor Relations	Political Science	Psychology	Social Sciences	History	Literature	Music	Philosophy	Interdis- ciplinary Subjects			Visual Arts	Foreign Literature
Architecture	45	0	19	61	125	16	10	12	10	19	161	6	234	359
Engineering	524	81	204	506	1,315	241	110	186	79	267	141	55	1,079	2,394
Humanities	165	21	340	198	724	250	268	66	234	212	65	33	1,128	1,852
Management	52	13	56	48	169	32	18	10	15	37	19	3	134	303
Science	187	14	110	380	691	224	211	150	176	267	106	50	1,184	1,875
Unclassified <sup>1</sup>	238	6	102	351	697	73	49	87	37	91	65	37	439	1,136
<b>Totals</b>	<b>1,211</b>	<b>135</b>	<b>831</b>	<b>1,544</b>	<b>3,721</b>	<b>836</b>	<b>666</b>	<b>511</b>	<b>551</b>	<b>893</b>	<b>557</b>	<b>184</b>	<b>4,198</b>	<b>7,919</b>

<sup>1</sup> This includes all students who have not yet made Course designations, plus a handful of unclassified graduate students.

DEPARTMENT OF ECONOMICS

**Table V Relative Distribution of Registrants in Undergraduate Electives by Broad Fields and by Schools insofar as they can be identified, 1968-69.**

School-Field	Visual Arts	Foreign Literature	Other Humanities	Social Sciences
Architecture	.45	.02	.19	.34
Engineering	.06	.02	.37	.55
Humanities	.04	.02	.56	.39
Management	.06	.01	.37	.56
Science	.06	.03	.55	.37

ROBERT L. BISHOP

**DEPARTMENT OF ECONOMICS**

This year has been memorable because of the heavy emphasis placed on student relations by the Department of Economics, and by the Institute as a whole. Despite this emphasis, a dedicated staff has also managed to carry on its other normal academic activities of teaching, research, and public service.

**RELATIONSHIPS WITH STUDENTS**

The Department has always taken justifiable pride in its reputation for close contact and ready availability and responsiveness to students. Yet, still more effort in this direction was called for this year than in the past. While it has been time consuming, and unquestionably has detracted from other academic activities, many fruitful results have and will come from the discussions and meetings we have had with students. Both faculty and students are to be commended for their constructive attitudes and efforts. The gains have justified the continuation of this cooperation, in order to reduce uncertainties and inefficiencies that arise from incomplete communication.

The Undergraduate Economics Association, under the presidencies of Charles F. Manski and Gregory K. Arenson, and the Graduate Economics Association under the presidency of Robert C. Merton, have had an especially active year. Besides their own organizational meetings, they held seminars to hear faculty discuss current problems or research, and in coffee hours for both students and faculty, they discussed with the Visiting Committee the problems of the Department as they saw them, organized the Department's Open House activities, and wound up the year with Agenda Day meetings in which the faculty, students, and staff participated in an open-ended and unstructured discussion. They were also active on student-faculty committees: the undergraduate committee headed by Professor Charles P. Kindleberger and composed, on the faculty side, of the undergraduate counselors; and the graduate committee

presided over by Professor Richard S. Eckaus with Professors Franklin M. Fisher and Evsey D. Domar as other faculty members. One consequence of the recommendations of these committees in the area of student-faculty relations, for example, will be a reduction in the number of students per faculty advisor from one-half to two-thirds present size.

The Department also arranged for the lively debate, sponsored by the Compton Lecture Series Committee, between Professor Milton Friedman of the University of Chicago and Professor Paul A. Samuelson which was well attended in Kresge Auditorium and broadcast over WGBH-TV.

The Graduate Economics Association (G.E.A.) has had a considerably longer life than the Undergraduate Association and has a more developed set of activities, which were continued successfully this year. The three major student-faculty social functions were the Christmas Party, highlighted by skits presented by both students and faculty, the Winter Dance, and the Spring Picnic. The G.E.A. seminars, organized this year by Hossein Askari, had their traditional initiation by a faculty discussion of the U.S. economy. During the year, the following distinguished economists participated in the seminars: Professors Oldrick Kyn of the Charles University of Prague, Alexander Gerschenkron of Harvard University, and Gary Becker of Columbia University; Dr. Sherman Maisel of the Board of Governors of the Federal Reserve System; Professors Hirofumi Uzawa of the Universities of Chicago and Tokyo, and Melvin Watkins of the University of Toronto; Sir Arthur Lewis of Princeton University; Professors Assar Lindbeck of the University of Stockholm, Menahem Yaari of Yale University, Frank Hahn of London School of Economics, and Friedman of Chicago. Two innovations this year were to have Professor Joan Robinson of Cambridge University in residence for several weeks, and an interdisciplinary debate on methodology between Professor Noam Chomsky of the Department of Foreign Literatures and Linguistics, Professor Samuelson, Professor Michael Piore, and Peter Bohmer, a graduate student. The many visitors we have had have enriched and broadened the view of the Department.

#### UNDERGRADUATE PROGRAM

Several changes have been made in the undergraduate program. The School's proposal to change the credit for humanities and social science subjects from 8 to 9 units per subject, coupled with an increase in the junior and senior humanities requirements from 32 to 36 units, was voted by the Faculty. Modest as this change may seem, no student now need take six subjects in order to carry a full 45-unit term load.

In addition to this change, the departmental requirement of 24 units of science or engineering electives in the junior or senior year has been



converted to unrestricted electives. It is further required, however, that a student must include 24 units of a coherent program in a field outside the Department, agreed upon by his Faculty Counselor. Such a field might be mathematics, political science, management, electrical or civil engineering, urban studies, or other areas, depending on the student's interests and the field's relationship to economics. Since, in some cases, this field can satisfy general Institute requirements, further flexibility in designing an undergraduate program is permitted. It had been argued by some, though by no means all students, that there were many subjects outside of science or engineering that, given their interests, had more educational value. By modifying the requirement to "coherence" and "relevance," we believe that it may prove of more educational value to students, whether motivated strongly toward natural or social science.

Another change, recommended by a committee headed by Professor Edwin Kuh, is a complete revision of the required undergraduate statistics subject, 14.381. This modification will be made during the coming year.

Urban Economics, 14.51, was offered at the undergraduate level for the first time and had an enrollment of approximately 50 students. At the request of the students, we will be offering Economic History, 14.71, for the first time next year. The need for an undergraduate reading seminar has been met, in a formal way, by adding a new subject, 14.09. We have under consideration offerings in the history of economic thought for undergraduates. While we have had a graduate offering in this field for years, limited student interest has warranted giving it no more often than biennially. This may now change.

Often in economics, as in other fields, requests are heard for more relevance in subject matter. As an indication of the desire to improve economic and social ills, such motivation can only be lauded. But a difficulty with economics is its growing complication as it moves toward more precise understanding of complex phenomena. Thorough grounding in the techniques and methods of analysis is necessary to come to grips with these problems and to search for economically viable solutions. Too often the most "obvious" problems require the most recondite understanding. When the demand for relevance represents impatience with mastering techniques and the painstaking search for the facts in all their complexity, easy, superficial "solutions" may be found that are inadequate to, or even exacerbate, the problem. The danger of this kind of "relevance" is that it leads to irrelevance. Undoubtedly, we can improve the quality of pedagogy by motivating students more highly to master theoretical and quantitative techniques, by emphasizing their relevance to particular problems while they are learning, and by never requiring them to take on faith the usefulness of their discipline.

**GRADUATE CURRICULUM**

Modest changes have been made in the graduate program this year. The Institute language requirement for the doctorate has been moved to the departments, and ours has eliminated it as a general rule. The Department faculty still reserves the right to require reading knowledge of a foreign language in cases where mastery of the major field or adequate thesis research requires it.

The addition of urban economics as a field for the Ph.D., which was instituted last year, has proved to be a popular one. Nearly half of our Ph.D. candidates offered it as one of their fields, and many are writing their dissertations in this vast, complex, and challenging area. This development is a welcome one and will require more staffing.

Changes in the draft deferment of graduate students had a smaller immediate impact on the first-year class than expected. However, nearly one-third of the second-year class have not continued as full-time students because of the new Selective Service regulations. The future impact the regulations may have cannot reasonably be predicted. It has created uncertainty in the size of the graduate student body both with respect to entering students and to those who leave with the understanding of guaranteed readmission.

The desire for greater emphasis on relevance, noted in the preceding section, is also evident among the graduate students. Especially in the first year of graduate work, when nearly all of the curriculum consists of developing theoretical and analytical tools, many students are apt to become disoriented and unable fully to bridge the gap between theory and application. Sheer mass of material makes it difficult to satisfy this need in the basic subjects. We have scheduled a new seminar next year under the leadership of one of our best teachers and practitioners of economics, Professor Robert M. Solow, to permit more time to be spent on the methodology of economics, its development, the state of the art, and where its study fits into the potential solution of larger economic problems.

There are a number of other matters with regard to subjects taught, faculty appointments, requirements for the Ph.D., methods of examination, and changing emphasis for the Master's degree, that are under active discussion among students and faculty, but they have not yet reached sufficient consensus to be reported.

**PERSONNEL CHANGES**

Visitors on the teaching staff this year included Professors Nissan Liviatan of Hebrew University, Jean Paelinck of Namur University, Peter Bernholz of the Technical University of Berlin, and C. Christian von

Weizsäcker of the University of Heidelberg, who returned again for the spring term. Professor Don Patinkin of Hebrew University was here for part of the year to conduct research.

On leave for the year was Professor Solow as George Eastman Visiting Professor and Fellow, Balliol College, Oxford University. The Institute for Development Studies, University College, Nairobi, had Professor Peter A. Diamond associated with it for half the year and Professor John R. Harris for the full year. In the spring term, Professor Diamond taught at Hebrew University, Jerusalem. Professor Peter Temin was at Nuffield College, Oxford University, in the spring term.

There have been a number of changes in the Assistant Professor ranks. Duncan K. Foley has been promoted to Associate Professor, and C. Duncan MacRae has taken a position with the Urban Institute. Two new appointments for next year are Robert F. Engle in econometrics and Ronald E. Grieson in urban economics.

The Department and profession suffered a grievous loss with the sudden death of Professor Miguel Sidrauski. In two short years, he had established himself as a coming leader in his field, a brilliant and profound teacher, and a warm personal friend.

#### RESEARCH AND OTHER ACTIVITIES

Although the style of the Department tends toward individual or small group research, there are a limited number of foci of these separate efforts. In an active Department such as ours, reporting of research activities must necessarily be highly selective.

In the statistics-econometrics field, Professor Kuh's project to develop a time-shared interacting computer program especially for econometrics work, TROLL, has over the past three years gone through the development stage and is now operational for research and for classroom development. Members of the Department have also been involved in large-scale model building of the economy. Professors Fisher and Kuh have been connected with the Brookings model and the latter was co-editor of and contributor to a second report on it. Professor Franco Modigliani has directed the development of the M.I.T.-Federal Reserve Board model aimed especially at the study of monetary and fiscal policy. Professor Harold A. Freeman is continuing work on factorial experimentation and time-dependent probability. Professor Fisher has conducted research on a range of problems in theoretical econometrics, for example, on index numbers, causality, and specification.

International economics has benefited from several papers in pure trade theory by Professor Jagdish N. Bhagwati, and in international finance by Professor Kindleberger. In the field of economic development,

Professor Eckaus's Indian study was published, and he is now applying these techniques to Chile. Professor Matthew D. Edel's interest in economic development in Latin America has resulted in several papers and a book to be published shortly. Professor Domar has continued his research into economic development of the Communist bloc countries.

The broad area of public economics has received increased emphasis from many members of the Department, and interest is growing. Research in urban economics involves much of the time of Professor Jerome Rothenberg. Professor Samuelson and Professor Foley made important contributions in the pure theory of public goods. The latter will also publish shortly, as co-author with the late Professor Sidrauski, a theoretical analysis of governmental fiscal and monetary policies. Professor Lester C. Thurow has published several papers on poverty, crime, manpower, and fiscal policy. Professor Piore has produced papers on ghetto manpower problems and labor supply. Professor Eckaus is engaged in research on the economics of education. Professor Temin published his work on the history of the Bank of the United States.

In industrial organization, Professor Morris A. Adelman has completed his major study of oil which will shortly appear. Professor Robert W. Crandall has carried forward work on the automotive and automotive-repair markets.

Professor Charles A. Myers produced new editions of popular books on personnel administration of which he is joint author, while continuing his research on the impact of computers.

Special mention should be made of the volume honoring the retirement of England's most distinguished economist, entitled *Value, Capital, and Growth: Papers in Honor of Sir John Hicks*. Professors Bhagwati, Fisher, Liviatan, Samuelson, and Solow were all contributors.

Professor Fisher was made a fellow of the American Academy of Arts and Sciences, was Irving Fisher Lecturer to the Econometric Society, and received the Military Applications Section Prize given by the Operations Research Society of America.

Public service activities of the Department are heavy. Advice, testimony, and consultation with governmental agencies ran to more than 15 days for a substantial proportion of the faculty. Sponsored by the State Department, Professor Everett E. Hagen gave some five months of time to the governments of Southeast Asia. Professor Paul N. Rosenstein-Rodan has continued as an active advisor to Latin American governments although in his second year of retirement. Professor Myers was Chairman of the National Manpower Task Force, and Professor Solow continued as a member of the President's Commission on Income Maintenance Programs. Professor Samuelson completed his term as

#### DEPARTMENT OF HUMANITIES

President of the International Economic Association and also served as member of the NSF (National Science Foundation) Social Science Commission. Professors Modigliani and Solow were members of the Executive Committee of the American Economic Association.

E. CARY BROWN

#### DEPARTMENT OF HUMANITIES

The total number of undergraduate registrations in the Department of Humanities has reached a new record again for the fifth consecutive year. Figures for 1968-1969 show an increase over 1963-1964 of 2,000 enrollments, from 4,902 to 6,907. Since these numbers include the relatively fixed population of undergraduates in the core curriculum, such gains represent growth in subscription to electives of the four major subject areas and in the Special Interdisciplinary Program. A more pronounced growth rate appears in the number of students in the several programs of Course XXI, whose numbers have increased over the same period from 94 in 1963-1964 to 210 in 1968-1969.

Growth of this kind, together with a process of curricular change, has generated certain problems for the Department, notably the matter of appointments and staffing. Since Humanities has the largest departmental responsibility to the core program of the first two years at the Institute, the scale of the staffing problem which we face is unique. It is further compounded by the fact that we have no graduate students from which to draw teaching assistants with the single exception of philosophy. Since we have replaced a single freshman subject with five one-year options, susceptible to steady revision, we have created a condition with an uncertainty principle of its own. The right of election which freshmen now exercise among five options in the first year indicates that no adequate forecasting of staffing needs has been possible during the past three years. The changing content of these subjects, together with the rise of some and the fall of others, has meant that the victims of the process have often been junior people on annual appointment. The only remedy would seem to be a stay in the process of curricular change by which a full year of lead time would be introduced before dropping or adding an option in the freshman program. Such a remedy itself would also become a constraint.

Of more fundamental importance, however, is the dilemma of definition which the core curriculum places on the junior faculty in particular and on the Department in general. Our uniquely heavy involvement in this program means, for instance, that the standard junior appointment to Humanities requires a person to spend virtually all his time in the

freshman or sophomore curriculum and almost none in elective subjects or seminars. Comparison with other departments at the Institute, which have no formal role in the core curriculum, draws the contrast quickly enough; junior faculty members of such other departments move far more directly to the areas of their special interest and competence, and begin their teaching careers far closer to the areas of their research, than is even remotely possible in this Department.

For the junior faculty in Humanities, this difference has led to an effort to reduce their total teaching load as a step toward greater parity with prevailing conditions of appointment in other major universities. The shift in 1969 from nine hours per term to a combination of six in one term and nine in the other is a move toward such parity, though an expensive one. The problem, however, of distance between teaching and research still remains. The dilemma raised by this issue is easy to describe; the type of core program in humanities which makes greatest educational sense for M.I.T. undergraduates, and which seems best to reflect the interest of students for whom the liberal arts curriculum must be closely compressed, is not necessarily the type of curriculum which works toward the professional advantage of those who teach it. Hence the problem of supporting research, both during the academic year and the summer vacation, remains real and pressing.

These conditions in themselves have tended to differentiate the tasks and roles of the junior faculty from the senior faculty in this Department, while leading to changes during the past year in the structure of internal governance in the Department. The three large sections of history, literature, and philosophy, for example, have met together on matters of curriculum, appointment, and educational policy with a frequency previously unknown. While the departmental policy committee retained its schedule of weekly meetings, it was increased at the request of the junior faculty and through its own meetings. In April four nontenure people were added to serve on the committee during the balance of the term. These were Robert S. Leiken, Mark A. Levensky, John McNees and Arthur R. Steinberg. Beginning in September, 1970, each section will be represented both by its chairman and an elected junior member. In every important way the Policy Committee has gained from the change. The emergence of stronger identity in each discipline and section will place a greater burden on this committee to maintain a sense of common purpose within the entire department.

#### CURRICULUM

For the past several years this space has been occupied most extensively by a report on changes in the freshman program. Prospects for 1969-

1970, though only in a relative sense, are somewhat less novel. The freshman option on Language, Culture and Community, designed a year ago by Allen Graubard and Sidney Goldfarb, will be dropped. Even if this option had received the enrollment it deserved, it could not have been repeated, since Mr. Goldfarb has resigned to accept appointment at Harvard, and Mr. Graubard will be on leave. The entry which is wholly new will be called Contemporary Moral Issues and will be planned by Gerald B. Dworkin and Boruch A. Brody. That noble experiment called God and Logic, which had an exceptional career in 1968-1969, broke down under the tension latent in its title and will be replaced by an altered version, Reason and Revelation, ostensibly less philosophic and more literary. The demise of God and Logic would seem among other things to reflect too much, rather than too little, truth in its label.

The most significant single new elective in the humanities curriculum this year was a subject offered during the spring on The Black Experience, planned and taught by Professor Richard W. Wertz and three prominent members of the black community in Boston, Canon James Breeden, Melvin H. King, and T. D. Pawley. A large number of visitors also took part in weekly panels of a subject introduced in direct response to demands by the Black Student Union for a subject directly related to the contemporary interest and condition of black Americans. At least three new electives will be offered in 1969-1970. Paul Bon Temps, a project director at the Education Development Center in Cambridge, will give an elective in the fall on Black Perspectives, drawn from the materials of history and biography. Hayward Henry, Chairman of Black Unitarian-Universalist Caucus, will teach a subject called Philosophy and Critique of Black Power. Floyd Barbour, a novelist, editor and anthologist, will teach an elective during the spring on Black Literature in America.

New electives in the Special Interdisciplinary Program this year included a subject on the History of Atomic Theory, taught by Professor Irving Kaplan from the Department of Nuclear Engineering; Film and the Anthropological Imagination, by Dr. Hans Guggenheim; the Interpretation and Judgment of Films, by Professor Robert Garis of the English Department at Wellesley College, who offered his subject at M.I.T. in the spring term while Professor Eugene Goodheart taught at Wellesley; and an Introduction to Film Making, offered by Mr. Edward Pincus as an experimental subject jointly sponsored by the Departments of Humanities and Architecture.

In September, 1968, a Steering Committee on Social Inquiry was formed, including members of the faculty and students from several

departments, to develop a program based on "a new approach to undergraduate education concerning the study of society," and directed toward "the social, cultural and philosophical problems that arise in an advanced industrial society." The rationale for these proposals rests on an effort to find a new basis for the critical examination of both modern social institutions and alternatives to existing methodologies used in the study of such institutions. To their proponents, these proposals represent an attempt, long overdue, to remove the study of the social and political order from traditional preconceptions of implicit value and ideology. To their critics, the program represents an unsubstantiated claim to have mastered the fact-value controversy. Although there are individual subjects and seminars, currently available or available in 1969-1970, which satisfy the criteria of social inquiry, the issue to be resolved is the proposal for an undergraduate major parallel to Course XXI.

#### EXTRACURRICULAR PROGRAM

The Department shared in the sponsorship of three major performances in Kresge Auditorium during the fall. The first was the appearance of Max Adrian in *Dear George*, a dramatization of G. B. Shaw's career based largely on his letters. Mr. Adrian's tour of American campuses, opening at M.I.T. on October 28, was presented by TRW of Cleveland.

During the first week of November, Julian Beck's Living Theatre presented six performances of its four-part cycle in Kresge, following its premiere at the Yale School of Drama and the Brooklyn Academy of Music. The *Time* reviewer described Beck's *Frankenstein*, with which the Company opened at M.I.T., as "the most original, powerful, and fascinating piece of theater in the country." But the *New Yorker* warned, in its own concluding comment on the same production, that all its own opinions were "subject to change without notice." Although audience response at M.I.T. ranged from admiration to rabid hostility, with Boston critics themselves divided, no one contested Walter Kerr's earliest observation about Beck's company: "With the Living Theatre, you will never be lonely." The unprecedented and uncontrolled congestion of the auditorium at *Paradise Now*, November 5, led to cancellation of the last two performances.

The Pennsylvania Ballet gave two performances in Kresge under the auspices of the Abramowitz Lectureship and the Lecture Series Committee on November 22 and 23. Probably the most successful single numbers were Balanchine's "Donizetti Variations" and a fresh, very original improvisation, "Time Plus," in a program which combined classical ballet with modern dance.



**SPACE**

The shortage of faculty offices in the Department of Humanities has become a very serious problem, despite the conversion of the old library lounge in the north wing of the Hayden Building into an area for classrooms and offices. Another yield of new space has materialized from the conversion of two bay areas in the north wing into modules of four small studies each. But it would seem now that our resources for further expansion in Building 14 have been exhausted.

During the summer of 1968, the Planning Office undertook major changes in two classrooms of Building 4. The changes were based on recommendations concerning designs proposed by members of the humanities faculty, which were effectively developed by Harry Ellenzweig, who served as architectural consultant. We hope that such annual remodeling of old classrooms can be expanded. The growth of enrollments in the Department of Humanities indicates that the majority of the faculty in this Department are still obliged to conduct discussion-based classes and seminars in rooms originally designed for lectures or recitations. In liberal arts colleges and universities, the physical separation of teaching space between science buildings and humanities buildings, whose design reflects the particular needs of each, was understandably omitted from the original architecture of the Institute. The absence of such differentiation at M.I.T. is the source of the problem we are trying to overcome. Those in the Department, who serve on an informal committee working with the Planning Office, have recommended an experimental program in which several different prototypes of design and furniture will be developed and tested for adoption in the early future. In the meantime, however, the need for additional office space and improved classrooms remains extremely urgent.

**PERSONNEL**

Professor Roy Lamson was honored by induction into the Order of the British Empire at a ceremony held at the British Embassy in Washington on June 12, 1969. In addition to his duties as director of Course XXI, Professor Lamson, during the past year, has served on the Discipline Committee, the Advisory Committee on Housing, and the Premedical Advisory Committee at M.I.T. He is also a member of Northgate Community Corporation, serving on its Executive Committee. He is a member of the Board of Directors of the Cummington School of the Arts, vice president of the Cambridge Society for Early Music, and continues to serve as chairman of the Marshall Scholarship Committee for the northeast area.

Professor Bruce Mazlish resumed his responsibilities as chairman of

the history section last fall. During the past year he published several articles, as well as a number of reviews, and had one of his books reissued as a paperback. He continues as a member of the Steering Committee on both the Group for the Study of Psychohistorical Process and of the Group of Applied Psychoanalysis, and serves as consulting editor of *History and Theory* and consulting editor in history for Macmillan and Company. During the past year he was a guest lecturer at Reed College and the University of Kansas.

Professor James F. Thomson was visiting professor at the Australian National University in Canberra during the summer of 1968. With Professor Judith J. Thomson, he gave a seminar on topics in the philosophy of mind and read papers at the Universities of Adelaide, Melbourne, and Sydney, and at Monash University. Professor Thomson continues to serve as consulting editor of the *Journal of Symbolic Logic* and of the *American Philosophical Quarterly*. After five years as chairman of the philosophy section, he has requested to be relieved from that post July 1, 1969, and will be succeeded by Professor Richard L. Cartwright.

Professor Louis Kampf published several articles during the past year, in addition to reading papers and delivering addresses at Queens College, The University of Washington, York University, Oberlin College, Michigan State University, Columbia University, The University of Rhode Island, the Association of American Colleges, and the Committee on College Composition and Communication. In December he was elected second vice president of the Modern Language Association of America.

Professor Cyril S. Smith was honored in the year of his retirement, by "A Discussion about Structure" at Endicott House on May 5-6, a symposium organized to reflect the uncommon variety of Professor Smith's intellectual career and accomplishments. The scholars who participated in the program represented the fields of biology, physics, anthropology, art history, and the visual arts. Professor Smith's own paper, "Art, Science, and History: Notes on their Historical Interaction," at the University of Oklahoma Symposium on the history of science and technology, was itself a prefiguration in April of the program in his honor in May. He also read a paper at a conference at the University of California in November, and served on the Council of the Smithsonian Institution, on a panel for the National Academy of Sciences, and as chairman of the Society for the History of Technology Committee on Honors. His Sarton Lecture, delivered at the A.A.A.S. (American Association for the Advancement of Science) meeting of December, 1967, was published in *Science*. His laboratory for the study of archaeology

materials was supported during the past year by the Sloan Fund for Basic Research at M.I.T. and by the National Endowment for the Humanities.

RICHARD M. DOUGLAS

#### LITERATURE SECTION

During the past year the section spent much of its time working on the core curriculum. Most of the subject offerings constituted an attempt to make the literary tradition relevant to the intellectual concerns of our students. Generally, the subjects purposely cut across the usual demarcations of genre and period ordinarily demanded by a literature curriculum. Where other areas of study proved useful in illuminating literary works, little hesitation was shown in using them. The section's curriculum review committee, which included two student representatives, carried on a continuous dialogue on the nature of the curriculum and the success or failure of subject offerings.

The curriculum committee decided to give literature majors a greater amount of freedom in planning their course of study. The primary objective of the major is not to give the student preprofessional training, but to allow him to develop a program of studies which will be broadly humanistic. Students will determine curriculum in close consultation with their departmental advisors.

The section has further broadened its offerings in creative writing, making it an integral part of the curriculum. Similarly, we have begun to give subjects in the making and criticism of film, and we hope to build this part of the curriculum into more than an incidental adjunct to literary education.

#### PERSONNEL

Professor George J. Bornstein, whose study of Yeats and Shelley will be published this fall by the University of Chicago Press, has resigned to accept an appointment at Rutgers. Professor Charles T. Cole has published a story, written two film scripts, and is at work on an Italian translation. Peter H. Elbow contributed two articles on teaching and Michael B. Folsom published an article on illuminated manuscripts. Professor Eugene Goodheart's book concerning the ego, published by the University of Chicago Press, has been entered in the competition for the Gauss Award; he has also published an essay on criticism and a review of books on Theodore Roethke. He taught a course in modern fiction at Wellesley on a faculty exchange arrangement between M.I.T. and Wellesley.

Professor Albert R. Gurney had several plays produced this year: *The Golden Fleece* at the Mark Taper Forum in Los Angeles and on

N.E.T., *The David Show* at the Players Theater in New York, and *Tonight in Living Color* (two one-act plays) at the Actors Playhouse. Professor William C. Green published with the Committee on College Reading, and Professor Andrew R. Hawley contributed articles both to *College English* and to *Motive*. An article on logic and fiction by Professor Alvin C. Kibel will be published by *College English*, while an anthology of non-fiction prose, edited by Professor Travis R. Merritt, was published by Harcourt Brace and World. Professor Wayne O'Neil, the new chairman of the section, gave a number of lectures to various groups on linguistics and education, and contributed articles to several publications in these two fields. Professor Barry B. Spacks published a collection of poems and gave poetry readings at both Wellesley and the University of Kentucky.

Miss Lillian Hellman joined the literature faculty during the spring term as visiting professor, teaching an elective on Reading and Writing to a group of special students who had previously taken writing subjects with Professor Cole, Professor Spacks, or Sanford Kaye.

LOUIS KAMPF

#### HISTORY SECTION

After extensive discussion this year, the section completed its proposal for a graduate program in comparative modern history, which we intend to present to the Faculty next year. This program is deliberately modest in scale, but ambitiously innovative in its aims. With a doctoral program now agreed upon, we propose next to focus our attention on a major reconsideration of our undergraduate curriculum.

Despite the general popularity of history electives, we intend to review the relationships among them from the standpoint of the undergraduate interested in concentration in the field of history, and again to ask what kinds of history seem most appropriate as elective subjects at M.I.T. The addition of three new assistant professors will favor this effort. James V. Kohl and Stuart M. Blumin, while teaching primarily in the first-year option in American Studies, will offer strength in Latin American history and historical sociology respectively. Dan S. White will join the Department from Harvard and will add strength to the field of German history. Looking back at the low ebb which history registrations reached six years ago, we are reassured now to find that registrations in the historically oriented subjects of the core curriculum are the highest in the entire core program. Extensive revision has been undertaken, however, in the sophomore subject, Society and Consciousness, and changes are also being made in the new freshman option, Conflict and Community in America.

Activities under the Ford Program in Comparative History were quickened by the presence of Professor J. L. Talmon of Hebrew University in Jerusalem, who was visiting professor of comparative history during the first term. Professor Talmon also led a Ford seminar on Ideologies of Elite and Violence. Other seminars included Afro-Americans and African Nationalism, led by George Shepperson, Professor of African and Commonwealth History at the University of Edinburgh, and Reflections on Youth Movements: Past and Present, led by Walter Laqueur, Director of the Institute of Contemporary History (London) and Professor of the History of Ideas at Brandeis. One disappointment under the Ford Program was the cancellation by Robert Lifton, research professor of psychiatry at Yale University, of his agreement to come as Ford Visiting Professor of Comparative History next fall; this came so late that we were unable to make other arrangements for that term. We were more fortunate, however, in our day-long Ford Conference on Comparative Modernization on May 16-17 at Endicott House, where Professors Charles Maier (Harvard), Terence Hopkins (Columbia), Ted Gurr (Princeton), John Womack (Harvard), and David Lowenthal (Boston College) made stimulating presentations on the subject that led to intense discussion on the part of members of the history section. Next year, we look forward to a two- or three-day Ford Conference on a similar topic.

We are also pleased to have the opportunity of filling a joint Ford Chair with the Department of Political Science; together, we look forward to making a major appointment sometime in the next year or so.

#### PERSONNEL

Owing to unexpected additional enrollments in the sophomore history subjects this year, we added Elizabeth Altman, Catherine Breen, Donald Koenig, and Lewis D. Wurgaft to our staff, the first three as part-time instructors. Mr. Wurgaft will continue with us next year as a full-time instructor, and Mrs. Altman as part-time lecturer in the spring term. In addition, Mrs. Helen Horowitz will join us as a part-time lecturer in the freshman option, Conflict and Community in America.

Jane de Long, Craig Eisendrath, and Mary Wakeman have resigned, although Mrs. de Long will return to teach one section of Conflict and Community next year.

We are pleased to note that Arthur D. Kaledin has been awarded tenure as Associate Professor. Professor Robert S. Woodbury will be on leave all next year, teaching at Georgia Institute of Technology. Cyril S. Smith, Institute Professor, becomes Emeritus, but we are delighted

to say that he will remain with the section. Richard W. Wertz will be on leave for a term under a grant from The Old Dominion Foundation.

Professional and civic activities of members of the section include, among many others, the following: Professor Richard M. Douglas has been appointed to the Advisory Council of the Department of History at Princeton. Professor E. Neal Hartley continued to fill the role of Secretary of the Faculty, carrying unusual burdens this year, in his usual exemplary fashion, while at the same time fulfilling his teaching duties in the section and serving as Institute Archivist. Professor Thomas H. D. Mahoney continued to serve as a City Councillor in Cambridge, was elected a Fellow of the Royal Historical Society, and was re-elected Chairman of the Massachusetts Fulbright Committee. Professor Robert M. Fogelson testified on the subject of riots before the Permanent Subcommittee on Investigation of the Senate Committee on Governmental Operations. Professor Nathan Sivin was a participant in the First International Conference on Taoism, Como, Italy, under the sponsorship of the American Council of Learned Societies, and also gave guest lectures at the University of Minnesota, the University of California at Berkeley, and the University of Kansas. Professor Robert I. Rotberg served as Research Director for ongoing research on Haiti for the Twentieth-Century Fund, and was elected Fellow of the Royal Geographical Society. Professor William B. Watson helped arrange a Harvard-M.I.T. colloquium on the Spanish Civil War, and gave one of the lectures. Professor Arthur Steinberg conducted a tour for the Archaeological Institute of America to Dallas, Austin, Los Angeles, and Stanford, and gave a colloquium at Harvey Mudd College, Claremont, California.

BRUCE MAZLISH

#### PHILOSOPHY SECTION

##### GRADUATE PROGRAM

The section has devoted considerable discussion this year to the structure of the graduate program, and special meetings have been held with the students to discuss departmental requirements. There was general agreement on the need to revise the program so that it would more realistically reflect existing professional demands. As a result, we have decided to abolish preliminary examinations, substituting for them subject requirements, and monitoring students' progress by a set of committees. Also, we shall allow students to submit a group of articles, in lieu of the more traditional thesis.

This year there were 20 students in residence. Of these, several will be leaving to accept teaching positions, one at Tufts, one at the University

of Washington, and one at the State University of New York at Oswego. One has accepted a research associateship at Rockefeller University, while another will spend the year in England on a National Science Foundation Fellowship, after which he will assume a position at the University of Illinois at Chicago Circle. In general, our students seem to be in strong demand at the better universities and colleges.

Applications for admission to the graduate program showed an increase, both in quantity and quality, over previous years. The percentage of acceptances also increased, and enrollment for next year should be at or near our quota of 30.

#### PERSONNEL

Professor Huston C. Smith published articles and reviews in various journals and was invited to give the Birks Lectures at McGill University. He received a Bronze Medal at the International Film and TV Festival of New York for his documentary film on Tibetan Buddhism. He was cited as Alumnus of the Year by the University of Chicago Divinity School, he served as chairman of the United States Committee of World University Service, and he chaired the nominating committee of the American Society for the Study of Religion. He also gave lectures at Williams College, University of Chicago, Stroud State University, Colby Junior College, Rockland Community College, Chowan College, Atlantic Christian University, Shaw University, Meredith College, Carroll College, Western International University, Claremont College, Marietta College, Mississippi State Philosophical Association, and the American Orthopsychiatric Association.

Professor Richard L. Cartwright presented papers at Brown University, Temple University, and Western Washington University, in addition to publishing several articles which appeared in the *Journal of Philosophy* and *Noûs*.

Professor Sylvain Bromberger attended a conference at the University of North Carolina and presented a paper. He delivered the Thalheimer Lecture at the Johns Hopkins University, and participated in a symposium at the University of Illinois. He continued to serve as a member of the advisory board of *The Philosophical Forum*, and also became a consulting editor for *Metaphilosophy*. He published an article in *The Philosophical Forum* and has other papers currently in the press.

Professor Irving Singer lectured at the Johns Hopkins University and, additionally, served as a consultant to the Institute Psychiatric Staff at their weekly conferences.

Professor Judith J. Thomson contributed to symposia at the University of Cincinnati and at the Western Division of the American Philosophical

Association. She also read papers at the University of Michigan, Brown University, and Columbia University. In collaboration with Professor Gerald B. Dworkin, she published an anthology of readings in ethics. She also wrote and edited an introduction to *Logical Constructions* by John Wisdom, while an earlier contribution to a symposium held at the University of Western Ontario has recently appeared in *Fact and Existence*.

Professor Jerrold J. Katz has continued to work on the philosophy of language, and has nearly completed a new book. He gave a class on his new work at Rockefeller University during the spring term.

Professor Jerry A. Fodor published a book concerning psychological explanations and published articles in the field of psychology in *Verbal Behavior and General Behavior Theory* and *The Business of Reason*.

Professor Boruch A. Brody delivered a paper at the western division meeting of the American Philosophical Association and published an article in the *Journal of Philosophy*. He additionally edited *Science: Men, Methods, Goals* and *The Major Works of Thomas Reid*.

Professor Dworkin collaborated with Professor Judith Thomson in an anthology of readings in ethics, published an article in *Dissent*, and contributed a review to *Philosophical Review*. In the summer of 1968 he received a summer fellowship from the National Endowment for the Humanities.

Next year our faculty will be augmented by the arrival of three assistant professors. Professor George S. Boolos was educated at Princeton University, at the University of Oxford, where he received the degree of Bachelor in Philosophy, and in our own department, from which he received the Ph.D. in 1966. For the last three years he has served as assistant professor in the Department of Philosophy at Columbia. He will help with the sophomore core curriculum and will also conduct classes at the graduate level in logic and set theory. Professor Robert Bolton, who is also a Bachelor of Philosophy in the University of Oxford, is now completing a thesis at the University of Michigan on Plato's philosophy of language. Professor Bolton's knowledge of Greek philosophy will make possible a wider coverage of the history of philosophy. Professor David M. Levin, a graduate of Columbia University, comes to us from Hofstra University. In addition to helping in the core curriculum, he will lecture on phenomenology and existentialism.

JAMES F. THOMSON

#### MUSIC SECTION

Professor Klaus Liepmann was on sabbatical leave of absence for the spring term and joined the faculty of the Technische Universität Berlin as



a visiting professor, conducting a subject in American Music — Past and Present.

In December, Professor Liepmann conducted the M.I.T. Choral Society and 47 members of the Boston Symphony Orchestra in a performance of Mendelsohn's *Elijah*. In May, the Choral Society, under the direction of the interim conductor, Allan Sly, offered a Walt Whitman Music Festival Concert, featuring the first performance of Ernst Bacon's *By Blue Ontario*, a cantata for contralto and baritone soloists, chorus, and orchestra.

In December, the M.I.T. and Wellesley Glee Clubs joined under the direction of Professor Liepmann to read through Handel's *Messiah*. In February and April, the M.I.T. Glee Club, under the direction of its interim conductor, John Oliver, gave joint programs with the Douglass College and the Mount Holyoke College Glee Clubs.

Professor Gregory Tucker coordinated the Humanities Series and Chamber Music at M.I.T. concerts, and also performed with students and faculty. In February, he and Professor John Buttrick gave a two piano recital at Kresge Auditorium, in which they performed concerti by Bach and Stravinsky and a sonata by Bartók.

Professor Tucker's *Suite for Two Flutes and Harpsichord* was played at Smith College while his most recent composition, *Elegie for Clarinet, Viola, and Piano*, received its first performance at the Gertrude B. Winquist Dedication on May 18th at Endicott House, when "Auro," a sculpture by Lyman Kipp, was dedicated in memoriam.

Professor David M. Epstein conducted the M.I.T. Symphony Orchestra in its concerts here and on tour. His *Trio for Strings* was performed on the West Coast and in Europe. A noteworthy performance was executed by the String Trio of the Boston Symphony Orchestra in Boston at Jordan Hall, where the work was received with enthusiasm.

John Cook, in addition to his duties as lecturer in music and Institute organist, coordinated the Organ Recital Series and the Thursday Noon-hour Concerts in the Chapel. His composition, *Flourish and Fugue*, was performed at the Cathedral of St. John the Divine in New York City and at M.I.T. by Marilyn Mason in her Kresge Auditorium recital.

Professor Robert S. Freeman, who joined this faculty in the fall of 1968, played both piano and oboe in concerts with faculty and students, and, in a concert with James Olesen, tenor, gave a lecture recital on Schumann's *Dichterliebe*. He published a work on the 18th century in several journals in the Field of Music, and read papers on Mozart at Yale University, Harvard University, and Dartmouth College.

During Professor Liepmann's absence, Professor Buttrick served as administrator for the Music Section. He gave two piano recitals at the

Gardner Museum and played music for two pianos in recitals with Professor Tucker in Brattleboro, Vermont, and at Kresge Auditorium.

Margaret Rohde, graduate of L'Ecole Normale de Musique, Paris, and presently head of the Theory Department at Longy School of Music, was a lecturer in music in 1968-69.

John H. Harbison will join the music section in the fall term as assistant professor of music. Professor Harbison is a graduate of Harvard University (A.B. 1960) and of Princeton University (M.F.A. 1963). A composer of works in all media, he also is a pianist and violist.

**COURSE XXI**

HUMANITIES AND ENGINEERING XXI-A

HUMANITIES AND SCIENCE XXI-B, PROGRAM 1

HUMANITIES AND SCIENCE XXI-B, PROGRAM 2

Enrollment in Course XXI has increased from 153 in 1967-1968 to 210 in 1968-1969, at the end of the second term. Of the current total, 22 students were candidates for second S.B. degrees in a five-year program, the highest number of such enrollments to date. In addition, Course XXI administered the programs of nine special students. From the total enrollment for three classes, '69, '70, '71, the choice of humanities disciplines places literature first, followed by philosophy, history, and music.

	History	Literature	Music	Philosophy	Total
XXI-A	9	17	1	4	31
XXI-B, Program 1	20	26	7	28	81
XXI-B, Program 2	22	50	3	21	96
Undesignated					2
	51	93	11	53	210

Although the enrollments in XXI-A and XXI-B, Program 1 are slightly higher than the enrollment in XXI-B, Program 2 (111 to 96), it should be noted that XXI-B, Program 2 has jumped from 36 students in 1967-1968 to 96, with the largest increase in literature (18 to 50). It is difficult to be certain of student choices of fields in the sophomore year. The enrollment in XXI-A and XXI-B, Program 1 was 24; that of XXI-B, Program 2 was 31, and it is possible that final choices of curricula by next fall may give evidence of a trend away from the degree combining humanities with science or engineering and toward concentration in humanities alone after the second year.

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The academic requirements of XXI-A and XXI-B, Program 1 remained essentially the same as in the previous few years, in offering the S.B. degree based on a program about equally divided between science or engineering subjects and humanities subjects. For the third- and fourth-year students the science or engineering fields chosen were as follows:

Life Sciences	19
Electrical Engineering	17
Physics	10
Mathematics	10
Chemistry	3
Aeronautics and Astronautics	2
Civil Engineering	1
Chemical Engineering	1
Geology	1

A program in psychology and humanities, included in XXI-B, Program 1, was selected by 16 students.

The Humanities Senior Seminar on education combined a study of the theory and process of learning and problems of teaching with observation and practice teaching in local schools of curricula devised by the seminar students. In addition to M.I.T. staff from several departments, visiting participants included Professors Marvin Bressler of Princeton University, B. F. Skinner of Harvard University, Vera John of Yeshiva University, teachers and administrators from Arlington and Brookline (Massachusetts) and Washington, D.C. schools, and from the Education Development Center.

Several students continued their interest into their theses, and many entered tutoring and teaching programs in local schools sponsored by M.I.T. The topic for the seminar was suggested by the class of 1968 and is an example of the desire on the part of many students to combine their studies in the classroom with experience in the community. The topic for next year is an inquiry into education at M.I.T.

XXI-B, Program 2, graduating its first senior class since its inception in 1966, offered a concentration or major in history, literature, philosophy, and music. Using the wide range of subjects within the curriculum of the Department of Humanities, the sections through their faculty counselors, provided effective undergraduate programs allowing considerable flexibility to students. Each of the sections has worked out its curriculum based on a concentration in a field of humanities, and a second field of study in a related field of humanities, modern foreign languages, social science, linguistics, or visual arts.

Special topics for study in each of the four fields, a tutorial arrange-

ment for students who wish to pursue a subject or problem beyond the range of the classroom, increased markedly. Planned for next fall are independent reading programs in literature and senior seminars in history, philosophy, and music.

On the whole, the continuing effort to provide good counseling has been more successful this year than last. Some forty faculty counselors worked with over two hundred students in numbers varying from two to seven for each counselor. The flexibility of Course XXI programs must be accompanied by careful counseling if the needs of the students are to be understood and served.

The senior thesis (required in XXI-A and XXI-B, Program 1, and XXI-B, Program 2, history; optional in XXI-B, Program 2, philosophy and literature) showed the wide range of student intellectual probing. Of the 33 theses submitted, 13 were in the field of history, seven in literature, five in philosophy, five in education studies. Other submissions included history and criticism of film, a novel, and a play.

The cessation of an extracurricular activity, The Course XXI Society, after ten years of operation should be noted along with increased participation of Course XXI students in political and community activities. Of the new Lillian Hellman Awards for Creative Writing, Course XXI students Robert Henning, Luis Clare, and Steven Rabinowitz won three of the five awards given. Three of the four Robert A. Boit Prizes went to Michael Lerner, Luis Clare, and Steven Girshick. Four students completed a year of studies abroad in France, Taiwan, New Zealand, and Israel.

In February, the illness of Mrs. Aida Blender, Secretary of Course XXI since its beginning, temporarily deprived us of the energies and devotion of a wise administrator and counselor.

ROY LAMSON

## **DEPARTMENT OF MODERN LANGUAGES AND LINGUISTICS**

### **DEPARTMENTAL CHANGE OF NAME**

As recently as 1960-61, we were appropriately called the Department of Modern Languages. An examination of the Institute catalogue for that year reveals that we were then offering 20 subjects in foreign languages, 12 in foreign literatures, and 4 in linguistics.

Our doctoral program in linguistics was introduced in the fall of 1961, and its meteoric rise to a position of preëminence made it necessary for us in 1965 to change our name to Department of Modern Languages and Linguistics.

In the past few years another development of great qualitative significance has occurred. We have assembled a solid group of foreign literature specialists, all of whom have published important works and are regarded with respect by their professional peers both in the United States and abroad. This development has brought about a remarkable shift of proportions in our program. The 1968-69 catalogue lists 37 subjects in foreign literatures, 28 in linguistics, and 23 in foreign languages. The time has therefore come for another *aggiornamento*.

In a department characterized by a variety of activity, the name cannot always be all-inclusive, but it can and should call attention to the major stresses. Our major stresses are foreign literatures and linguistics, which are our two terminal areas of study. Our foreign language subjects are purely instrumental. In reality, then, we have become a Department of Foreign Literatures and Linguistics. The change of name, effective July 1, 1969, will simply confirm and advertise an accomplished fact.

#### GRADUATE PROGRAM IN LINGUISTICS

During the spring term Professor Noam A. Chomsky was John Locke Lecturer at Oxford University and Shearman Lecturer at University College, London. In 1968, his book, *Language and Mind*, was published by Harcourt, Brace and World.

Professor Morris Halle has been awarded an A.C.L.S. (American Council of Learned Societies) fellowship for 1969-70 and will be on leave.

Professor René P. V. Kiparsky is completing a year's leave, part of which he spent in India, doing research on Indian linguistic theory and on Sanskrit grammar.

Professor James W. Harris has completed a book on the subject of Spanish phonology, which will appear in the fall of 1969. The publisher is the M.I.T. Press.

Professor John R. Ross taught at the Linguistic Institute of the University of Illinois in the summer of 1968 and gave a course in the fall of 1968 at Brown University on the structure of English.

Linguistics research in progress continues to be extremely diversified. Professor Chomsky is preparing studies in syntax and semantics, while Professor Halle is working on a handbook of phonetics, on the history of English stress, and on Slavic accentuation. Professor Kenneth L. Hale is training American Indians as linguists in their own languages, presently a Papago Indian, Mr. Albert Alvarez. This project entails writing a manual of grammar in the language itself and then translating it into English. Professor Ross is close to completing a long work on English phonology, and is engaged, along with George Lakoff, in the preparation

of a lengthy book on abstract syntax. Professor Harris is doing further research in the area of Spanish phonology, and is composing a first-year college Spanish textbook, which will be published by Harcourt, Brace and World.

#### GRADUATE PROGRAM IN LANGUAGES

In March 1969, the Committee on Graduate School Policy voted to eliminate the Institute-wide foreign language requirement for the doctorate, allowing each department to make its own decisions in this area. Nine of 23 departments deciding to retain the requirement in one form or another are the Departments of Mechanical Engineering, Architecture, Electrical Engineering, Physics, Psychology, Chemical Engineering, Aeronautics and Astronautics, Political Science, and Linguistics.

The Committee also voted to eliminate, as inadequate, the one-term reading subjects in Scientific French, German, and Russian.

Starting in the fall of 1969, the Department will offer two-term subjects with a reading stress, involving both general and technical materials, in French, German, Russian, and Spanish, while continuing to offer two-term subjects with an oral emphasis in the same languages.

In order to facilitate the independent study of other foreign languages, the Department has begun to accumulate in its language laboratory a library of tapes which provide instruction in languages currently spoken in every part of the world.

#### UNDERGRADUATE PROGRAM IN LITERATURE AND LANGUAGES

Professor Martin Dyck will be on sabbatical leave during the fall term of 1969-70. His replacement, Professor Richard C. Exner of the University of California at Santa Barbara, will teach two subjects: 23.22, Modern German Fiction, and 23.032, The Nature of Literature.

Professor Dyck's book, *Novalis and Mathematics*, first published in 1960, was issued in a second edition in 1968. Following up his very favorably received study, *Die Gedichte Schillers*, he is now preparing a second volume on Schiller's poetry.

Professor Robert E. Jones's book, *Panorama de la Nouvelle Critique en France*, will soon go into a second edition. He is at work on two full-length studies, one dealing with the plays of Giraudoux, the other with the life and works of Nerval.

Professor Krystyna Pomorska is composing a book on Pasternak, and is compiling two anthologies on Russian prose and Russian formalism.

At a meeting held on March 2, 1968, the departmental Visiting Committee recommended that a Course XXIII major, comparable to that in Course XXI, be introduced. After a number of discussions, the foreign

#### DEPARTMENT OF POLITICAL SCIENCE

literature staff drew up a proposal, which has now been submitted to the appropriate committees. The proposal is for a double major, involving French, German, or Russian literature and a science or engineering specialty. It includes the following required subjects: a senior thesis, an advanced seminar, six departmental elective subjects restricted to one of the literatures mentioned, and 54 units of elective subjects restricted to one of the engineering or science curricula. This would leave 49 units of unrestricted elective subjects.

The heterogeneity of our student body makes it advisable that such a program be flexible enough to allow for a variety of possibilities. The Department proposes to teach literature as a study, not only of works organized toward beauty, but also of documents in such fields as philosophy, history, government, and psychology. It further proposes to go beyond literature per se, analyzing its relationships with the other arts and with other aspects of civilization. Majors would be encouraged to cross-register at Harvard University or at Wellesley College for subjects which are not offered by us and which can contribute to a coherent program. They would also be urged, if they are interested in area study combinations, to invest some of their unrestricted elective capital in appropriate subjects offered by the Departments of Humanities, Political Science, Economics, and Architecture. If approved, this double major would go into effect in the fall of 1970.

WILLIAM F. BOTTIGLIA

#### DEPARTMENT OF POLITICAL SCIENCE

In a year characterized by exceptional change in academic departments at M.I.T. and across the country, the Department of Political Science was no exception to the rule. As the Department moved into its second decade, change in faculty composition, in curriculum format, in research, and in leadership have accompanied the continued performance of established activities. They have also placed heavy and sometimes unexpected loads upon the Departmental structure.

At midyear, Professor Ithiel de Sola Pool completed three years of extraordinary leadership as head of the Department. In his unanticipated reassumption of the post, he displayed personal energy and professional sacrifice clearly beyond the call of duty, and we are grateful for his labors. But, as he should prefer, the most convincing account of his stewardship is quantitative. Since 1965-66:

1. The number of full-time undergraduates majoring in political science increased from 62 to 75

2. The number of undergraduates enrolled in political science courses rose from 329 to 530
3. The number of graduate student applications for admission increased from 82 to 221, while the annual Institute quota expanded from 50 to 74
4. The number of full-time faculty members or equivalents was 26 in 1965-66, contrasted with 35 today.

Output, as indicated by degrees awarded, underwent less change. For the three years, the total production of doctoral degrees reached 39, and Master's 13. This compares to the 1963-66 period average of 20 doctoral and 12 Master's. The significance of this time series is a matter for later comment.

Expansion and growth, as the Department moved toward maturity, were inevitably accompanied by losses. One anticipated case was, nonetheless, severe — the retirement of Professor Norman J. Padelford, who in the exact sense of the word “established” political science at M.I.T. Not only was Professor Padelford the first genuine political scientist at the Institute, the first section and then department Head, but he was also the first to breach skillfully and successfully the barrier between our discipline and the engineering, physical, and biological sciences.

Professor Padelford's professional competence, his Yankee common-sense, and his personal integrity were the foundations on which our program began. We cannot adequately acknowledge our debt for this service, but we can express our enthusiasm that he will continue his teaching and research on a shared basis with the Department of Naval Architecture to help develop directions in new sea policies. Thus he demonstrates once again his unquenchable spirit for new adventures that endears him to us all.

Professor Fred C. Iklé, on leave of absence to help the RAND Corporation establish new domestic capabilities, concluded that he should oversee the execution of programs he had instigated and, accordingly, joined the Corporation permanently. Professor Frank Bonilla, also on leave in research activities in Brazil, accepted the invitation of Stanford University to join their expanded program in Latin American affairs. These losses are not only unexpected and substantial but are also novel. They mark the first time any tenured member of the Department had succumbed, in Dean Emeritus John E. Burchard's felicitous phrase, to “the determined advances of academic seductors.”

Other departures occurred on other levels. After a decade as student, professor, and active member in M.I.T. affairs, Professor Frank C. Colcord resigned to become Chairman of the Political Science Department of Tufts University. An exceptionally able teacher, a scholar with a



special skill in interdisciplinary work, a warm colleague, he will be sorely missed. Departing to Haverford College is Professor G. Eric Hansen, whose richly deserved reputation in teaching was Institute-wide. Professor John D. Steinbruner will be taking up a post at Harvard University after notable work in defense policy, and Professor Matthew A. Crenson leaves, after a year in urban affairs, to continue his work at Johns Hopkins University.

Additions help sustain our ranks. Professor George W. Rathjens, who spent this year in collaboration with Professor William W. Kaufmann in systems analysis, will join the Department permanently, and Professor Michael Lipsky comes from Wisconsin to build our strength in urban affairs. Professors Nazli C. Field and Christopher Schaefer will be joining the staff in the field of international relations. Nonetheless, we will not only have to find suitable replacements in the defense, Latin American, and European comparative fields, but we must also substantially strengthen our resources in the American government field. The enlargement of our instructional and research capacity is a matter of great importance.

The three years of exceptional progress that quantitative indices show, and the specific losses and additions just recorded, are only partial indicators of our current situation, with its potentials and problems. Especially after three years of absence, one is impelled to note the sharp shift in outlook and mood characterizing faculty and student body alike. In 1965-66, political science at M.I.T. was an accepted course of study with a distinguished national professional reputation and with a few lingering expressions of skepticism as to its role at the Institute. In 1968-69, the first two of these conditions continued, but, it is fair to say that the political uses and social consequences of technology and science have, in a singular way, captured the attention of M.I.T. at large, as well as becoming a central national concern. As our enrollments rise and interest in the values of the utilities of our discipline increases, our obligations in research and teaching become a matter of attention scarcely conceivable in 1965.

Accordingly, this spring we have intensified our efforts to improve and expand our educational activities, giving particular attention to the undergraduate level. A joint faculty-student committee, chaired by Professor William E. Griffith, built upon the work of previous years to recommend major changes in the Bachelor's program, including establishing the policy of substantial undergraduate instruction by all senior faculty members. Simultaneously, Professor Frederick W. Frey led a committee on graduate studies which recommended far-reaching changes, building upon the advisory committee structure and revisions in examinations

of a year ago. A series of faculty meetings in late spring discussed and endorsed the majority of proposals, and a faculty-student implementation group is at work this summer in order to make some measures operative in the fall.

Inevitably, the curriculum adjustments affect the research and other activities of the Department and will call for different organizational procedures. Students made proposals on these matters in the spring and can be expected to participate increasingly in Departmental affairs in the future. Participation in Departmental affairs, however, can cover a wide spectrum of activities and it is important to relate expanded student efforts to the improved functioning and more effective working of the Department.

An academic department is not a community, no matter how often or loosely that word is used, and it does not purport to overview the private and unprofessional life of its faculty and students. It is, of course, simply an instrument designed to carry out inquiry and to conduct training at as professional a level as possible. Consequently, the key question concerning the character of participation in Departmental affairs is always: What contributions to improved research and teaching are expected to result? We anticipate this will be the explicit principle guiding faculty judgments next year.

In all we do, our predominate objective must be providing effective scholarship and scholars in our area of inquiry. Here, the record of the annual number of degrees awarded, summarized earlier, must be a subject of concern. For many of our students, the elapsed time in residence, especially the intervals between general examinations and the completion of dissertation, seems capable of acceleration. The Department expects to explore carefully the causes for undue delay and to attempt to ameliorate them wherever possible to assure uninterrupted periods of study.

While Department members gave extraordinary attention to curricula and student affairs, their professional research work continued unabated. Professional articles or contributions in book form appeared in a number of principal journals.

Professor Myron Weiner received the Watumull Prize in the History of India from the American Historical Association for his book on the Indian National Congress, published by the University of Chicago Press in 1968.

Members of the Department have served as consultants to the following governmental agencies:

Department of State: Professors Hayward R. Alker, Lincoln P. Bloom-

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field, Griffith, Everett E. Hagen, Lucien W. Pye, Eugene B. Skolnikoff, and Weiner

Department of Defense: Professors Kaufmann and Pool

Department of Housing and Urban Development: Professors Robert C. Wood and Oliver E. Dial

Bureau of the Budget: Professor Kaufmann

A.I.D.: Professors Roy E. Feldman, Frey, Stuart D. McIntosh, Pye, and Pool

The Industrial College of the Armed Forces: Professor Alker

Nixon Pre-Inauguration Task Force on Urban Affairs: Professor Alan A. Altshuler

U.S. Agency for International Development: Professor Hagen

National Science Foundation: Professors Pool and Harvey M. Sapolsky

National Security Council: Professor Pye

Members of the Department have also served as consultants in the following private organizations:

Brookings Institution: Professor Kaufmann

Center for Inter-American Relations, Inc.: Professor Ernst Halperin

Ford Foundation: Professor Donald L. M. Blackmer

RAND Corporation: Professors Griffith, Kaufmann, and Pool

Shaw Research Corporation: Professor Bloomfield

Simulmatics Corporation: Professor Pool

Urban Institute: Professor Kaufmann

WGBH: Professors Leonard J. Fein and Skolnikoff

World Book Encyclopedia: Professor Pye

The following have also served on Institute committees:

Advisory Committee on Decentralization to the Boston Model Cities

Administration: Professor Altshuler

Committee on Academic Performance: Professor Colcord

Committee on Educational Policy: Professor Hagen

Committee on Graduate School Policy: Professor Padelford

Committee on Nominations: Professor Pool

Committee on Student Environment: Professor Feldman

Committee on Evaluation of Freshman Performance: Professor Hagen

Subcommittee on Thesis Research Policy: Professor Padelford

Information Processing Services Committee: Professor Pool

Committee on Curricula: Professor Sapolsky

Committee on Libraries: Professor Weiner

The faculty activities in community and neighborhood affairs and public purpose organizations, in which services were provided on a voluntary basis, were of special interest this year.

Professor Colcord served as a member on the Board of Directors of

the Alliance of Cambridge Settlement Houses, as well as treasurer and member of the Board of Trustees of REACH, Inc.

Professor Johnson is executive director of CIRCLE Associates, Inc. and the New England Community Development Corporation, a business promotion and economic development complex engaging in economic research, business project organization, and some political organization.

Professor Robert I. Rotberg is a member of the Steering Committee of the Cambridge School Affairs Advisory Committee and a member of the ad hoc Cambridge Save our Schools Committee.

Professor John S. Saloma is a member of the Massachusetts Civic League.

Professor Bloomfield is Chairman of the Parish Committee of the First Parish Church in Cohasset.

Professor Wood is on the Board of Directors of the Museum of Science and a member of the Board of Directors of the United South End Settlements.

ROBERT C. WOOD

### DEPARTMENT OF PSYCHOLOGY

By the end of the year, the M.I.T. Department of Psychology reached its fifth year as a Department, and its seventh as a doctoral and research program, housed since the fall of 1962 in its own laboratory building on Ames and Amherst Streets in Cambridge. Seven years ago, some predicted that the program would never fill the building; two years later, the building was overcrowded, and this crowding has now grown to the point where lack of new laboratory space has become a major obstacle to further growth.

Our intention to grow further may seem a strange assertion against the background of our rapid initial growth and in the context of shrinking federal support, but we are too young a Department to stand still. By Institute standards, we are an exceedingly small group, particularly if measured against what we are trying to do. Even if we did not wish to increase the present scope of our activities, we would still have to increase our resources, since we are doing almost too much with what little we have.

A faculty of 12, unchanged in numbers for the last four years, has been teaching vast numbers of students, rising from 200, seven years ago, to more than 1400, in each of the last two years. No one in our group wants to curtail this activity, but it is becoming increasingly clear that undergraduate laboratory space and additional staff are needed, no matter how we structure our curriculum.

The same small faculty, with their colleagues on the Departmental research staff and their 24 doctoral students, have been engaged throughout last year in over 20 interrelated research projects and programs. These laboratory investigations continued to follow the same three tracks that had been laid down initially by the department: studies of brain and behavior (psychobiology); work on perception and learning (experimental psychology); inquiry into early stages in the development of individuals and their means of interaction (social-developmental psychology and psycholinguistics).

Over the years, these three tracks have increasingly converged, and one measure of ultimate success may lie in a complete coalescence of our three principal areas. Nevertheless, we must remain watchful lest one or another activity be left behind. We all realize that indiscriminate expansion could blur our structure; different parts of the Departmental program need special strengthening in different years. Looking at the last year, it is quite evident that our three major themes have received somewhat unequal emphasis: brain-behavior studies have flourished, as have studies of perception, but work on early development and social interaction has had less than its share of attention and support.

Here, as in teaching, the picture is deceptive; much has been done with little resources, but, for the next year or two, major efforts need to be made in the third area of our Departmental program to make sure that the progressive coalescence of the other two areas, brain and behavior (psychobiology), and perception and learning (experimental psychology) does not extrude the third, whether it remains centered in psycholinguistics and related social-developmental studies, or broadens to include larger portions of cognitive psychology.

It is a peculiar feature of our program that growth, at the present stage, need not mean a drastic increase in total staff. Much can be accomplished by internal rearrangements, particularly by converting some research-staff positions into regular faculty appointments and by maintaining extreme selectivity in appointments from the outside. In terms of funding, this means that the most beneficial developments, by far, would be the establishment of endowed chairs, distributed over the main areas of our program, and a proportional increase in laboratory space.

As we look forward to the next five or seven years of this program, we can be certain that the Department will remain committed to its distinctive approach — an effort to account for man's behavior in terms of fundamental mechanisms. It is this common goal that gives unity in spite of the diversity of our methods. To paraphrase what was said in a programmatic speech to the M.I.T. Corporation seven years ago: "We all share the conviction that a science of behavior must eventually cope

with its subject matter in the way other sciences have tried to cope with theirs: to explain, predict and, where possible, to control. In attempting to reach this goal, psychology will continue to borrow methods from other natural and social sciences, and from mathematics. The unity of the field lies in its central question, not in any one method that would be limited to psychology as such."

It is for those reasons that the research and teaching staff of M.I.T.'s Department of Psychology now includes, besides experimental psychologists, such diverse specialists as neuroanatomists and biophysicists, neurologists, biomathematicians, linguists and analytic philosophers. Their seemingly disparate backgrounds are complementary and, in nearly every case, overlapping with those of some colleagues who might have fitted into quite a different setting if the Department had grown up in a more traditional environment than that of M.I.T.

Together, this unusual group taught 23 undergraduate and graduate subjects during the year past, while engaging in the conduct of their 20 research projects. These teaching and research activities will be briefly described.

#### TEACHING

The total undergraduate enrollment in psychology subjects during 1968-69 was 1336. This figure marks a small decrease from 1967-68, when total undergraduate enrollment was 1388, but is still above the corresponding figure for 1966-67, when it stood at 1168. It is obviously too early to say whether the rapid expansion in our undergraduate enrollment has now leveled off, but we have already pointed out, as we have in previous years, that this large enrollment continues to be generated by a small teaching staff, meeting their undergraduates in very large groups.

This is particularly true of Professor Hans-Lukas Teuber's introductory subject, 9.00, which attracted a combined fall and spring enrollment of 782 students. This number is so close to the total size of the Institute's undergraduate class in any given year that further expansion is not to be expected, or, rather, feared. What is desperately needed is additional junior staff to man tutorials and small discussion sections and to guide laboratory projects. Although understaffed, these activities have run alongside the large weekly lectures which were given this year, in the evening, as two-hour sessions, in the Compton Lecture Hall. We owed this beautiful setting to the hospitality of our colleagues in physics.

The lectures were videotaped and replayed on various occasions for purposes of review. It is hoped that in the coming year, television can be combined with a computer-assisted interrogation system to increase opportunities for two-way interchanges with the instructor. However, the major lack remains the one we have already cited — the absence of suffi-

ciently numerous project laboratories that would run either concurrently with the one-term introductory subject or follow afterward, in a second term.

Two other undergraduate subjects, both with sizable enrollments, though none as impossibly large as the introductory subject, have undergone considerable change in the direction of project-oriented undergraduate instruction. These two subjects spanned the entire range of our program, one involving physiological psychology, 9.01 and 9.02, the other, social psychology, 9.70. Dr. Gerald E. Schneider reorganized the undergraduate physiological psychology subject by adding some laboratory demonstrations, and will extend this reorganization in the coming year, aided by a welcome subsidy from the Institute's fund for curriculum development. Dr. Mary C. Potter assumed responsibility for the undergraduate social psychology subject and completely changed its format from the previous one, a pure lecture sequence, into a series of small group sessions, in which each group reported on its own group processes, and undertook various experiments to influence interactions within the group.

On the graduate level, the enrollment was 119, distributed over 10 different advanced subjects, making the combined graduate and undergraduate enrollment total 1,455. Among these, the introductory proseminar was reduced last year to a single term, the fall term, with intermediate-level seminars in each of the three areas of our program taking the place of the second proseminar term. These intermediate-level seminars are still undergoing various changes, yet it is likely that they will again replace the second term of the proseminar in the coming year.

Among the more advanced offerings to doctoral students, Professor Walle J. H. Nauta's series of lectures and demonstrations in brain morphology continued to attract cross-registrants from other departments within and outside the Institute, as did the seminar in sensation and perception, conducted by Professors Richard M. Held and Whitman A. Richards, and the seminar in psycholinguistics by Professors Jerry A. Fodor and Merrill F. Garrett. A unique feature of the spring term was the seminar on local and global processes in perception, a special series of lectures and demonstrations by Professor Bela Julesz, who worked on his computer-generated stereo patterns during his tenure as visiting professor in the Department, in the spring of 1969.

As in previous years, the graduate students held mock conventions in which their own research projects were presented in the format required for a national or international scientific meeting. These meetings, arranged by the graduate student colloquium committee, were scheduled twice, once in the fall and spring semesters.

Pressure for admission into the graduate program continued undiminished. For each of the past two years, the total number of inquiries exceeded 200, and a hardworking and often baffled committee on admissions, headed by Professor Held, has maintained an influx into the program of 10 new graduate students in 1967-68, and 7 in 1968-69. For the coming year, 9 new graduate students are expected as the result of a review of 206 applications.

#### COLLOQUIA

As in the past, the series of Departmental colloquia was an additional vehicle of graduate and postdoctoral education. In the past year, there were fifty such colloquia. Nineteen of the speakers were visiting from abroad, their countries of origin ranging from England, France, and Germany (four, five and six speakers, respectively) to one each from Canada, Holland, Hungary, and Italy. About two-thirds of the colloquia were followed by evening discussions between the students and their invited speakers, often extending to midnight and beyond, in a faculty home.

#### VISITING STAFF

During 1968-69, the Department had the privilege of welcoming three visiting professors. Their terms in the Department ranged from three weeks in the case of Professor Donald M. MacKay, Professor of Communications at the University of Keele, Staffordshire, England, to the five weeks spent by Professor Kao-Liang Chow from Stanford, a visit jointly sponsored by Professor Francis O. Schmitt's Neurosciences Research Program and by M.I.T.'s Department of Psychology, and to a full spring semester in the case of Professor Julesz, who, while here on leave from the Bell Telephone Laboratories, taught a seminar and finished a book.

There were also five postdoctoral fellows in residence, two in the area of brain and behavior, Drs. Carl C. Chi and Hans J. Zeier, working with Professor Nauta's group; two in perception, Drs. Louis O. Harvey and Charles F. Stromeyer III, working, respectively, with Professor Richards and Held; and one in psycholinguistics, Dr. John E. Limber.

#### ARRIVALS AND DEPARTURES

Among faculty, we have to report one arrival and one departure. The arrival represents the return of Dr. Emilio Bizzi, who had worked in the Department as a research associate and lecturer until one year ago, when he went to the University of Milan. He has now decided to leave there and to accept an associate professorship in our Department. As



can be seen from last year's report, Dr. Bizzi won general acclaim for his brilliant discoveries on frontal-lobe function through microelectrode studies of the visuomotor mechanism. His return will strengthen the role of these advanced methods in research and training in the area of brain and behavior, while providing an important linkage between that area and the experimental work on perception.

Our delight in having Dr. Bizzi return to the Department is tempered by an unexpected departure. We were saddened by Professor Wayne A. Wickelgren's decision to leave the Institute for the University of Oregon, where both he and his wife Barbara, a neurophysiologist, were offered positions. Our regrets are not diminished by Professor Wickelgren's insistence that his decision to move was exclusively motivated by the lack of a suitable academic appointment in the Boston area for his wife. During his years at the Institute, Professor Wickelgren had established a highly personal style in mathematical psychology, primarily in studies of short-term learning. His astounding productivity in the laboratory and his enthusiasm as a teacher make him impossible to replace.

Among our postdoctoral fellows, three of those in the Department are departing, Drs. Chi, Harvey, and Zeier. Dr. Chi has accepted an appointment at Yale University, after two years of postdoctoral training in neuromorphology with Professor Nauta; Dr. Zeier, who also spent two years in the neuroanatomy laboratory, working predominantly with Dr. Harvey J. Karten on the avian brain, will return to his native Switzerland to launch a laboratory at the Swiss Polytechnic Institute in Zürich; Dr. Harvey, who worked for the last year with Professor Richards on vision, expects to spend a second postdoctoral year at the Institute for Perceptual Investigations in Soesterburg, Holland. Two other postdoctoral fellows will remain for yet another year in our Department, Messrs. Limber and Stromeier. Edward C. Walker, who was with us while on a predoctoral fellowship in linguistics, will remain in the Department during his first postdoctoral year.

For the coming academic year, we expect several additional visiting investigators and postdoctoral fellows. In Professor Teuber's laboratory, Dr. Mark P. Bryden from Canada will be a guest investigator, while Dr. Ronald Wayne Hurt from Washington, D.C. and Dr. Fritz H. Körner from Tübingen, Germany, will be special research fellows. All will participate in the new program of research on late after-effects of brain wounds in 130 veterans of the Korean War. This work proceeds currently in the Department's neuropsychology laboratory and in the Clinical Research Center.

In Professor Nauta's laboratory, Dr. Robert L. Boord will start work as a special fellow, on a project to be carried out jointly with Dr. Karten

and with Dr. Lawrence S. Frishkopf in the Research Laboratory of Electronics. Another postdoctoral fellow, Dr. John C. Hedreen, expects to work primarily with Professor Nauta.

In the laboratories mainly concerned with perception, a short-term visit is expected from Dr. Athanase Tzavaras from Paris, who will observe experimental procedures in Professor Held's group. For the entire year, Dr. John M. Foley from Santa Barbara, California, will devote himself to mathematical analyses of space perception, in collaboration with Professor Richards.

In Professor Alan Hein's group, Dr. David Miller will continue to serve as consultant and research associate on studies of early development.

#### HONORS AND OUTSIDE ACTIVITIES

As in past years, the Departmental faculty and staff received invitations from other institutions, in the United States and abroad, to present special lectures and seminars, or to participate in various congresses or symposia. Taken together, these outside appearances exceeded the number of invited outside speakers to the Department to such an extent that we need not feel too guilty about exploiting other institutions through our local program of invited colloquia.

In the United States alone, over 100 lectures, special papers, and seminars were given by individual members of the Department, precluding any detailed listing. However, we should mention that the Department participated even more actively than before in the educational efforts of various medical schools and teaching hospitals in the Boston area, by way of more than two dozen teaching conferences and seminars in 1968-69. Eleven of these were given by Professor Nauta.

Within the Institute, Professor Nauta continued to serve on the ethics committee on the use of human subjects, and Professor Held chaired a C.E.P. (Committee on Educational Policy) subcommittee concerned with the ROTC issue. Professor Richards served on the Graduate School Policy Committee, and Professor Teuber was chairman of the advisory committee for the Center on the Visual Arts, and continued to be a member of the Clinical Research Center Board.

At the national level, Professor Nauta continued as a member of the National Institute of Mental Health selection committee for research career awards and continued to serve on the Biological Stain Commission. He maintained his consultant service for the Walter Reed Army Institute of Research.

Professor Held continued as a member of the Board of Scientific Advisors of the American Psychological Association. Professor Teuber con-

tinued on NASA's Biosciences Committee and accepted membership on the Training Committee in Behavioral Biology of the National Institute of General Medical Sciences. He served on the Head Injury Panel of the World Federations of Neurology and Neurological Surgery. In the spring of 1969, he chaired a section of their International Meeting on Head Injury.

With regard to other international activities, we should record that Professors Nauta and Teuber were elected to the Central Council of the International Brain Research Organization (IBRO-UNESCO). Professor Nauta took part in the symposium on the Autonomic Nervous System at the University of Toronto. Professors Held and Teuber were invited by the French Government to the Paris meeting on the Functions of Gaze, in May 1969, and Professor Garrett was asked to represent the Department at the forthcoming International Meeting on Psycholinguistics in Bressanone, Italy. Professor Hein was invited to lecture in Paris and Marseilles during June, 1969, and Dr. Thomas E. Twitchell represented us at a Ciba Conference on Early Development in London, in November, 1968. Both Professors Schiller and Teuber were asked to speak at the International Congress of Psychology, to be held at the end of July, 1969, also in London.

Professor Teuber also participated, by invitation, in a NATO summer seminar on Optical Information Processing at the Enrico Fermi School of Physics in Varenna, Italy, in July 1968. This summer school also permitted us to invite one of our graduate students to attend the seminar. Mr. Robert A. Smith was accordingly chosen and went to the conference with special support by the National Science Foundation.

Professor Teuber also delivered invited addresses at the National Institute of Neurology in Mexico City, the German Psychological Association in Tübingen, Germany, the Salpetrière and Ste. Anne Hospitals, as well as the École des Hautes Études, in Paris, and the German Neurological Society in Baden-Baden.

Professor Fodor, who spent part of the fall term as a visiting professor at the University of California at San Diego, subsequently gave several lectures at Cambridge and Oxford Universities.

Finally, we should note that several members of the Department will take part in the second Boulder Conference arranged for the summer of 1969 by Professor Schmitt's Neurosciences Research Program. These include Drs. Bizzi, Held, Karten, Nauta, and Schneider. Also this summer, Dr. Lennart Heimer is working at the Marine Biological Station of the National Institutes of Health in Puerto Rico, Professor Fodor is in Oxford, and Professor Chorover is teaching at the University of California at Berkeley.

**RESEARCH PROGRAM**

As last year's report has shown, research activities in the Department have grown to a point where even the most abbreviated account strains the format of these annual descriptions of our activities. This year we shall therefore publish our report on Departmental research as a separate pamphlet and limit ourselves here to a brief outline of ongoing work, in each of the three areas of our program.

In the area of brain and behavior, efforts have spanned the range from anatomical studies of vertebrate brains in diverse species to work on human behavior in the presence of focal brain injury. Our concern has been with a few basic questions: the way in which information is processed in the visual system; the role of the olfactory system in the coding and storing of odors, and the importance of deep brain structures, particularly those called "limbic," in the regulation of moods and motives, and possibly in the initiation of processes leading to the formation of memory traces; and, lastly, the ways in which an organism's own movements enter into its perceptions.

To cite only a few examples: Work in Professor Nauta's group, exploiting the Fink-Heimer modification of Professor Nauta's famous stain for degenerating nerve terminals, continues to reveal an unsuspected complexity of sensory circuits in vertebrate brains. During the year, this work has covered sharks and reptiles, birds and lower mammals, as well as primates. In combination with electron-microscopy, this new stain can demonstrate exquisite details of synaptic connections, permitting the first observations on the redirection of nerve fibers after very early injury in the mammalian brain (Schneider and Nauta). Some of the neuroanatomical work has proceeded in collaboration with a field station in Puerto Rico where Professor Nauta, and Drs. Heimer and Karten have worked and lectured for a number of weeks.

In the study of man's own brain, new efforts were being made in Professor Teuber's group to define behavioral tasks that would be sensitive to the late after-effects of focal brain wounds in previously healthy adults. In a collaborative study with the Harvard Neurology Department and the National Institute of Neurologic Diseases, Professor Teuber and his group are currently examining 130 men with head injuries dating from the Korean War, comparing their present condition with that seen in long-standing injury cases from World War II, and after more recently acquired lesions sustained in warfare or in civilian accidents.

Special attention is given to the status of the visual, auditory, and somatosensory systems after various focal brain wounds, with the twofold objective of validating objective tests for the detection of pathology, and of gaining insight into the neuronal mechanisms underlying perception.

In addition, a special survey is being made of acquired disorders of memory in man ranging from slight difficulties in the retention of particular kinds of material to profound and disabling amnesias. Attempts are also being made to see how much of the ultimate learning disorder can be predicted from measures of the initial loss, found in the first weeks and months after the brain wounds. This work is being carried out jointly by Drs. Suzanne H. Corkin, Richards, Rita G. Rudel, Twitchell, and Teuber, together with several graduate students.

An increasing concern with fundamental mechanisms of learning is also characteristic of the current work of Professors Chorover and Schiller, who combine computer-averaging and microelectrode techniques with certain neurochemical procedures, in their continued search for neural correlates of learning, especially in the "limbic" regions of the brain of lower mammals. A novel approach to these problems is afforded by the discovery of one of their students, Foteos Macrides, that single cells in the olfactory system of mice react with distinctly different patterns of electric discharges to the odor of familiar and unfamiliar animals.

Professor Schiller, in the meantime, has pushed his analyses of control of eye movement in monkeys to deeper structures. He continues to find nerve cells that seem to monitor outflow-commands to the eye muscles, suggesting a critical role in those regulatory loops that are concerned with feed-forward, as well as feedback mechanisms in the control of voluntary movement and in the maintenance of stability in perception.

This work begins to make contact with the discoveries of Dr. Schneider who has clearly demonstrated the existence of at least two visual systems in rodents, one presumably concerned with knowing where things are, and the other with knowing what they are. A similar duality of visual pathways in the brain of birds had previously been shown by Dr. Karten. The concern with the riddle of multiple visual systems has led to a three-day conference on subcortical vision, held as an international workshop under the sponsorship of the Department. The conference assembled 44 investigators, on June 26-28, 1969, with 7 of the participants coming from abroad. The conference, which will be published, was chaired jointly by Professor Schneider of our Department and Dr. David Ingle, now at the Harvard Medical School.

In the areas of perception and learning, Professor Held and his co-workers and students pursued their program of experimentation on the bases of sensorimotor coordination. On purely functional grounds, they too were led to postulate that there are two kinds of visual mechanisms, one concerned primarily with localization of objects (where things are) and the other, with their identification (what they are). These experiments continue to exploit distorted visual input, such as that produced

by prism spectacles, to analyze the conditions under which the wearer of such spectacles can adapt, so that he ceases to misreach for objects, or no longer perceives the optic distortion.

Earlier work in Professor Held's laboratory had shown that active, self-produced movement by the observer is necessary to produce such adaptation. It now turns out that active movement can permit adaptation to opposite forms of distortion presented in succession. Thus, a prism wearer can adapt to a set of prisms worn over one eye apex-to-apex, then base-to-base, producing different distortions depending on whether the eye turns left or right, and depending on prism orientation. Repeated exposure to the two kinds of spectacles, while moving actively about, leads to adaptation to both, a result which strains our understanding of the visual system and underscores the role of active movement in perception.

Some of the methods and theories developed by Professor Held's group are currently being extended to special tests of prostheses, such as the Boston arm and similar electronically steered artificial limbs, originally proposed by the late Norbert Wiener, and now under continuing development in Professor Robert W. Mann's laboratory in the Department of Mechanical Engineering.

Intensive concern with the role of movement in perception has also been characteristic of Professor Richards' work during the last year. By measuring convergence movements of the eyes during size and depth estimations by normal observers, and by those with disorders in their visual field or oculomotor system, Professor Richards has found a new way of classifying different forms of stereovision. Similarly, by recording scanning and fixation movements of the eyes, during inspection of various patterns, Professor Richards and his co-workers have come to the conclusion that the visual system computes a "center of gravity" for complex arrays, but does not scan edges and corners as such. The detection of features can apparently proceed in parallel, and independently of this computation, suggesting again a duality of basic visual mechanisms.

Questions about rates of processing of information also play a major role in Professor Wickelgren's studies of short-term and long-term memory. He continues to be concerned with rates of acquisition and decay, particularly for short-term memory traces. Some of this work has also been applied to cases of specific memory disorders.

In the area of social-developmental studies, two major trends could be discerned over the last year: the work on early stages in the acquisition of perceptual-motor coordination by kittens, monkeys, and human infants, and the intensive analysis of first-language learning. Professor Hein, Dr. Rhea M. Diamond, and their collaborators and students extended the range of their experiments on the need for active exploration

in young kittens, by combining various drastic variations in early rearing (rearing in darkness, exposure to the visual world under conditions of passive transport rather than active locomotion) with very early removals of visual cortex. It turns out that the conditions crucial for the acquisition of normal sensorimotor coordination, such as active locomotion and sight of one's limbs, are also crucial for the reacquisition of perceptual-motor function after cortical removals in the very young animal. Further studies concern the acquisition by normal animals of eye-limb coordination, in direct parallel to the work on the emergence of visually guided reaching in human infants by Dr. Twitchell.

Joseph A. Bauer and Professor Held continued to obtain similarly striking results of special rearing with baby monkeys under conditions where the animal is prevented from seeing its own limbs. The control exerted by the young animal over its unseen limbs is currently being studied and compared with the total incoordination which appears, as soon as the animal is permitted to see its limbs, and which persists for many days before that limb is properly "mapped" into the animal's visual system.

All of these studies are beginning to indicate an unexpected interplay between innate and learned factors in early development, and the same picture emerges from ongoing investigations of first-language learning and other psycholinguistic work in the department. Professors Fodor and Garrett and their students and co-workers continued their analysis of reactions by very young infants to a great variety of speech sounds. When gauged by ease of conditioning and by transfer of conditioning from one sound complex to another, perception of speech sounds by the human child seems to be quite special. Apparently, those sounds that can represent phonemes, that is, normal components of speech in at least some languages, have greater attention-getting value for the baby than non-speech sounds, and this long before he can talk himself. What is still more remarkable, phonemes that are deemed similar by adults also seem to be equally similar for the preverbal child. The results strongly suggest that there are innate feature detectors in the human auditory nervous system, and that these detectors have to be "hooked in" to produce language comprehension and language production. An obvious corollary of this idea would be the prediction that partially deaf children must receive hearing aids quite early, during their first year of life, rather than afterwards, since it is known from experimental work on other sensory systems that innate feature detectors tend to wither away if they are not used during certain critical periods in early development.

These sketchy descriptions of current work in the Departmental laboratories are given here merely to indicate the range of activities, and to

emphasize the rather considerable unity of themes within the diversity of methods. We believe that psychology, of necessity, cuts across many disciplines. If we aspire at prediction and perhaps even control of behavior, in animal and man, we must be ready to explore the structure and functions of the brain, with all the resources that a highly technical institute can provide. We must be willing to consider the major manifestations of behavior on all levels, from simple sensory and motor acts, to those involving perception and memory, language and logic. In this sense, psychology can be the essential link between the natural sciences and the humanities. Ultimately, we want to know what goes on inside ourselves when we perceive and move, feel or express emotions, learn, think, and remember. It will certainly take us more than the next seven years before we can see even the vaguest outlines of an answer to these questions, but we believe we are underway.

#### CONCLUDING REMARKS

This recital of our activities for the year should not end without some reference to the broader historical context into which these activities were placed. The academic year just past was one of turmoil on many campuses, even though M.I.T. experienced less disruption and engaged in more rational discourse than many other institutions.

Some of this discourse went on during the Institute-wide days of concern, and on that occasion, the Department of Psychology reaffirmed certain guiding principles which may have been quite apparent from its year-by-year practices. The principles were formulated well before the present concern about the role of science became prominent, but they seemed timely enough to be adopted by the Department at the end of the year, as an expression of our joint convictions about the proper role of behavioral science. The principles were stated by the chairman of the Department, Professor Teuber, seven years ago, in his speech to the M.I.T. Corporation, on October 1, 1962. We thought it fitting to close the Departmental report for the year by quoting from the end of that speech:

“It is of vital importance for us to get to the moon and the planets, but some of us should be permitted to apply what we know about nature to man himself, and to find out what goes on inside our brain. The justification is the same as for all the other sciences: the satisfaction of an essential curiosity about nature. As Whitehead put it, we do not discover in order to know, we know in order to discover. Psychology has reached the stage, perhaps for the first time in its history, where it is ripe for discoveries.

The resulting knowledge may have frightening aspects, as all increases



in knowledge. When we defined the field, we said that psychology tries to *account* for the behavior of organisms, but to *account* for something, in most sciences, means trying to *explain, predict*, and where possible, to *control*.

We instinctively shrink from the idea of explanation of ourselves, and prediction and control have even more sinister aspects. So far, there is little ground for concern, because of the extremely rudimentary state of the field. Once the knowledge is there, it will present an ethical challenge as great as the recent applications of atomic physics. As Lord Adrian said, he who will first be able to explain and to cure paranoia, will have found a means of producing it.

How psychological knowledge is to be applied will be a question for our conscience and our values which come before and are basic to any scientific effort. In teaching in this critical field, we must therefore instill a set of values consistent with the guidelines of our own personal lives, a sort of Hippocratic oath for behavioral science, never to do harm, not to use individuals as mere means to ends, to persuade rather than to coerce. The same humanitarian values are essential to the application of physics, of technology, and of the social sciences. Here, too, psychology is a living bridge between natural science and the humanities.”

HANS-LUKAS TEUBER

## CENTER FOR INTERNATIONAL STUDIES

A number of major projects advanced last year in the four main areas of Center interest, economic and political development, international communication, military and foreign policy, and studies in communism, revisionism, and revolution.

### PROBLEMS OF ECONOMIC AND POLITICAL DEVELOPMENT

The Center's joint project with the Oficina de Planificación Nacional in Chile (ODEPLAN), now in its second year, has undertaken five studies in operational development economics. Dr. Peter B. Clark began constructing long-term planning models on the Chilean economy, an extension of the Center's work in India on such models. Three Chilean economists are cooperating in the endeavor, which is under the supervision of Professor Richard S. Eckaus. Dr. Jere R. Behrman is carrying out a second project in model design, which will be a short-term model with flexible prices to study the effects of stabilization policy. Dr. Lance J. Taylor, working under the supervision of Professor Hollis Chenery of Harvard, is developing criteria for project analysis, which will be applied to projects

in various stages of completion in the fields of agriculture, industry, and public utilities. Under the supervision of Professor Carlos Diaz-Alejandro of the University of Minnesota, Dr. Edmar L. Bacha of Yale University has been studying the comparative cost advantages of the Chilean economy within the framework of the Andean and the Latin American Common Market. Finally, Professors Paul H. Cootner and Franklin M. Fisher have undertaken a supplementary study of both short- and long-term prospects in copper prices. The entire project is under the joint direction of Professors Max F. Millikan, Paul N. Rosenstein-Rodan, and Richard S. Eckaus.

The Chile project has educational as well as research dimensions. Although the work on these projects precludes regular teaching assignments, all members of the M.I.T. team in Chile have been participating in discussions and seminars in universities and academic institutions. In addition, there are now three Chilean graduate students in the later stages of their work for the Ph.D. in economics at M.I.T.

The two final manuscripts of a three-volume series, which emerged from the Center's collaboration with the Centro de Estudios del Desarrollo (CENDES) of the Central University of Venezuela, have been sent to the M.I.T. Press. Professor Frank Bonilla has drawn up a study based on intensive interviews with 200 people, selected for their influence in the political, economic, and cultural spheres of Venezuelan life. Dr. José A. Silva Michelena has examined conflict and consensus patterns among some 34 groups in the population, selected for their relevance to priority development problems.

*The Role of Popular Participation in Development*, edited by David Hapgood and published by the M.I.T. Press last May, describes the conclusions and recommendations of an intensive six-week study of Title IX of the Foreign Assistance Act, which was organized by the Center in the summer of 1968, at the request of the Agency for International Development (AID). The seminar brought together scholars from various disciplines and officials from AID to explore the implementation of Title IX, which instructs AID to place emphasis on "assuring maximum participation in the task of economic development on the part of people of the developing countries through the encouragement of democratic, private, and local government institutions." Professors Millikan and Lucian W. Pye were chairmen of the conference.

Professor Frederick W. Frey with his staff completed the initial phase of a comparative analysis of the attitudinal and behavioral dimensions of the modernization process among nations at varying levels of development. The resulting bibliography, edited by Professor Frey with Peter Stephenson and Katherine Archer Smith, was published by the M.I.T.

Press in June 1969. Although reduction in funding forced the cancellation of field work, the project proceeded on a reduced scale in two directions: methodological studies of patterns of association in small- and medium-sized organizations, and secondary analysis of survey research on attitudinal modernization.

A study of Indian voting behavior, through the computer processing of Indian electoral data, continued under the supervision of Professor Myron Weiner, in cooperation with a consortium of social scientists at eight universities. Now under way is the extensive process of collecting all 1951 and 1961 district census handbooks and electoral data from all national and district elections since independence.

Work continued under Professor Pye's direction to assess the different psychological and cultural attitudes and predispositions which have been critical to the national development of several different societies in Asia.

#### INTERNATIONAL COMMUNICATIONS

Two intensive examinations of communications in time of war were completed by Barton Whaley, as part of Professor Ithiel de S. Pool's ongoing project in international communications. An empirical study of surprise and deception in warfare, with special reference to the strategic rather than tactical level, will be published in 1970. Case studies are included of 168 battles from 16 wars during the 1914 to 1969 period. A second manuscript discusses strategic information processing, preceding surprise attack, through a detailed case study of warnings of the impending German invasion of Russia on June 22, 1941.

Professor Pool's large-scale effort to simulate the communications pattern of the Soviet Union has continued. A computer model of the Soviet population was confronted with two communications scenarios, designed to model the diffusion of news about the Cuban missile crisis and the assassination of President Kennedy. Work on this was done by Mr. Herbert Selesnick. Dr. Rosemarie Rogers has now run a third Soviet simulation, concerning the first public evidence of the dispute between the Soviet Union and China. She has also begun a fourth simulation on Soviet public reaction to the events in Czechoslovakia during 1967-1968.

The ADMINS computer system, which has facilitated many of the recent simulations at the Center, continues to be refined by Stuart D. McIntosh and David M. Griffel with Professor Pool. Since Mark III ADMINS became available for public use three years ago, approximately one hundred people have used the system. To facilitate use, the various manuals on the program have been expanded, edited, and integrated. Standard statistical routines have been added to the analyzer subsystem, and the whole system has been modified to provide output suitable for other

systems. Visitors to M.I.T. consistently report that no other facility currently available for primary and secondary data handling is so advanced. Having implemented Mark III to the limit of its capability, McIntosh and Griffel have been developing a more powerful system, Mark v, which they hope to implement on a computer different from C.T.S.S. (Computer Time-Sharing System).

Professor Hayward R. Alker, Jr., is completing a book on mathematical models of complex political systems. Specific examples include power conflicts in developing countries, arms races, peace-keeping efforts of the United Nations, and the efforts of supranational economic organizations to transcend nationalistic loyalties and decision making orientations.

As part of an extensive study of group identity and political change, Professor Harold R. Isaacs has begun an examination of the current phases of the changing patterns of Negro group identity in American society, attempting an historical approach to black separatism along with scrutiny of the present movement. Dr. Ai-li Chin, working in cooperation with Professor Isaacs, has developed an interviewing system and begun to amass data in her nationwide study of the current experience and position of the Chinese, including both descendants of earlier immigrations who have been gradually moving out of the Chinatowns and more recent immigrations from the professional and business classes of pre-Communist China. In addition, a book by Mrs. Chin and her husband Robert Chin, who is Professor of Psychology at Boston University, appeared in October 1969 from the M.I.T. Press. It reports, in detail, research published in China, not previously available in English, as well as the activities of the psychologists there, and evaluates how the psychologists' changing relationship to the government has affected their research, particularly in reference to the nature of psychological man.

A systematic, sociological study of contemporary history, by Professors Daniel Lerner of M.I.T. and Morton Gorden of the University of Pennsylvania, was published last August by the M.I.T. Press. In the analysis of their ten-year panel survey of opinion among French, British, and German elites, the authors focus on a range of issues concerning national security, prestige, prosperity, and the significance of European transnational institutions. They examine the conflicts between the elites' assumptions and their preferences with regard to the relationships among the three traditional world powers and with the United States.

#### STUDIES IN MILITARY AND FOREIGN POLICY

Professor Lincoln P. Bloomfield and Amelia C. Leiss have conducted two major studies in elaboration of their design study of arms control and local conflict in developing areas. The first, by Professor Bloomfield,

uses political-military exercises to explore more deeply some of the dilemmas facing U.S. policy vis-a-vis conflict control problems. The second, by Miss Leiss, with the assistance of Geoffrey T. H. Kemp, is an analysis of arms transfers to less developed countries and the relationship between arms supply and third world conflicts.

A third study of the impact of defense expenditures on economic development in less developed countries, by Professor Millikan and Professor Emile Benoit of Columbia University, completed its first stage, a macroeconomic analysis of the relationship between the share of national product devoted to defense and the rate of economic growth. The study has developed indices of real changes in defense expenditures and in GDP (Gross Domestic Product) for 44 developing countries during a period of five to fifteen years, between 1950 and 1965. Analyses are now being made of relationships between defense burden and economic growth and some of the characteristics of the economy or the defense structure that may explain these relationships.

Robert R. Beattie is developing a framework for the computerization of data on local conflicts since World War II, with a view to systematic recall of conflict-minimizing factors and policy measures. The initial design of the system was completed and made operational in time to use it in conjunction with the political-military exercises in local conflict control mentioned above.

Professor William W. Kaufmann, in collaboration with David S. Mundel and Professor John D. Steinbruner, held a series of seminars on the operation of the Planning, Programming, and Budgeting System (PPBS) in government decision making. Jointly sponsored by the Kennedy Institute of Politics, the meetings reviewed the record of PPBS in the Department of Defense and other government agencies in light of the various criticisms that have been directed against it. A report is being prepared of these meetings, which will be available in the fall of 1969. A longer study on the problems of the Federal government and the role of PPBS is in progress.

In cooperation with the Kennedy Institute of Politics and the Center for International Affairs at Harvard University, the Center also sponsored a series of meetings to review the military posture of the United States and to consider possible changes in the posture once the war in Vietnam has ended. The basis for these meetings was a series of papers prepared by Professor Kaufmann. Portions of these papers have been used in an article in *Newsday*, in testimony before the Subcommittee on Economy in Government of the Joint Economic Committee, and in an article for *Fortune*.

Professor Eugene B. Skolnikoff continued his research on the inter-

national political consequences of technological advance, including specific implications for organization of the international system, U.S.-French space relations, and the consequences of space technology proliferation.

**STUDIES ON COMMUNISM, REVISIONISM, AND REVOLUTION**

Two manuscripts were completed under the project's auspices last year. The first volume of Professor John A. Marcum's political analysis of the Angolan revolution was published by the M.I.T. Press in the fall. A volume on Czechoslovak communism, edited and annotated by Dr. Robin A. Remington, also appeared in the fall from the M.I.T. Press, and included documents not previously available in English from the Center's growing library on communism, revisionism, and revolution. The documents extend from the political and economic controversies which precipitated the crisis, through the crisis in Czechoslovakia and the other Communist satellite countries, to the Soviet invasion and response. Two books in progress were those of Professor William E. Griffith on the relations between Bonn and the East and Professor Ernst Halperin on communism and guerrilla warfare in Latin America. Professor Donald L. M. Blackmer began research on the leftist politics in Europe. Professor Uri Ra'anan, a research affiliate of the Center, now at the Fletcher School of Law and Diplomacy, continued writing on Soviet ideology and policy toward underdeveloped countries, particularly in the Middle East and Southeast Asia.

**MAX F. MILLIKAN**

## ALFRED P. SLOAN SCHOOL OF MANAGEMENT

**T**he year just ended was an important one in the Sloan School's brief history. It was important both because it demonstrated the soundness of the strategy which the School has followed in the past and because it indicated that this strategy must continue to evolve if the School is to deal effectively with the challenges that lie ahead.

In comparing the School's performance to its own very high standard of past performance, the year 1968-69 was a good year. It saw the long-considered idea that the School should extend its competence in the field of management across the broadest spectrum of institutions begin to have a real and positive effect on several programs. The Master's curriculum was the one most directly affected during this year, but it is already clear that the changes there have influenced and will continue to affect the curriculum planning in other programs. The School's broadened focus is also reflected in this year's admission of students in several programs seeking to further their preparation for careers in the management of education, and urban and public affairs, in addition to the strong continuing flow of students aiming at careers in industry. Perhaps the most obvious effect, however, was organization of an experimental and highly successful four-week Program for Urban Executives which was offered twice during the year. Faculty changes during the year added strength to several important areas, and research programs gained both thrust and momentum. Student participation in the School's affairs increased and contributed substantially to our progress. The School also strengthened its already good relations both with other departments at M.I.T. and with various administrative agencies within the Institute, upon whose services the School increasingly depends. Relations with other institutions ranging

from industrial to governmental, to other universities and schools, were developed to such an extent that various forms of cooperative programs are now under consideration. By most standards, therefore, the year just ended has been a busy and productive one. In the following pages I will report in more detail the accomplishments of all those within the School who worked so hard to bring these developments about.

If the year had brought only these changes it would have been an important one for the School; but it brought other changes as well, changes related not to the past but to our perceptions of the future. Before turning to the pleasant task of reporting on last year's activities, I think it is important also to consider the future briefly.

The fundamental question facing the School in the future is not whether it can continue to make important contributions to the practice of management; it clearly can and will. The question that we face is whether these contributions are consistent with the magnitude and urgency of the management problems that face our society. Management is coming to be recognized, not only by those of us in the Sloan School who might be understandably biased in our views of such matters, but also by a substantial number of concerned and thoughtful people outside the School, as the limiting ingredient in most of the attempts which are being made to deal with the great problems of our times. We are told, and we believe, that management ideas and men willing and able to manage the increasingly complex institutions by which we deal with these problems are in short supply and very badly needed. The Sloan School, through its programs of teaching and research, contributes both to new management ideas and to the preparation of men willing and able to manage effectively. We can take satisfaction from the magnitude of our current contribution, but we must also remain aware of the unfilled need and be prepared to take whatever steps we can to try to meet it.

We must continue to work hard to use the resources now available to the School as effectively as we know how. We must continue to experiment with ways to increase our own productivity. We must be willing to shift resources from successful ongoing activities if we find they can be employed more effectively in other ways. We must, in short, manage our own limited means to deal with the critical management problems in our society in such a way that they will have the maximum effect.

But these internal rearrangements will not be all we must do if we are to meet responsibly the needs which exist today in the field of management. We must also expand the resources available to us. We can do this, I think, in two ways. The first and most obvious way is to find new sources of financial support for the School among those individuals and organizations who believe in the importance of the School's various programs.



The second way is to find ways to draw more effectively on the resources of other organizations. This may require the formation of new organizations but, in general, would involve existing organizations where a joint activity, drawing on the resources of both the School and the other organizations, could further the purposes of both. The beginnings of such developments already exist. Through the mechanism of cross registration in programs of other Schools and departments both inside and outside M.I.T., students can supplement the subject offerings available to them in their own program. At the present time the Sloan School suffers a trade deficit in cross registration, with more students from outside the School taking subjects within the School than vice versa. This deficit is itself evidence of student interest in joint programs which might be developed more fully. Faculty members, too, are engaged in a variety of arrangements with external organizations which suggest that the interest of all concerned is being served and that even more imaginative arrangements might deserve to be considered. Thus, external relationships with a wide variety of organizations, whose resources might usefully complement those already available to the School, must be added to the list of internal changes which the School must be prepared to undertake if it is to respond appropriately to the crisis of management that currently confronts our society.

Change is a subject with which the School is familiar. It has characterized its development to date and was demonstrated in the activities of the year just ended. In reviewing these activities it is appropriate to relate them to the historical process from which they have emerged. But it is also appropriate to remember the magnitude of the challenge we face and to relate what the School is, to what it must become.

#### THE TEACHING PROGRAMS

We have a rough indicator of the School's total annual teaching output in management studies in our count of student-subjects. (One student taking four management subjects for the academic year, for example, equals four student-subjects.) Teaching activity in the School, measured in student-subjects, has more than doubled over the past decade. The enrollments of Sloan School students, which we can control by admissions policies, have increased during this same period according to plan, but enrollments in management subjects by M.I.T. students outside the Sloan School have increased at a higher rate and continue to increase. The total Sloan School student population enrolled in our several programs again shows a moderate and controlled annual increase. Enrollments in our undergraduate programs have leveled off after a three-year rise, but the student population in both our Master's and our doctoral programs in-

creased. Enrollments in the School's executive development programs also rose as the result of our prior decision to expand annual enrollment of Sloan Fellows from 45 to 50 but is primarily attributable to the School's introduction of a new Program for Urban Executives which I shall describe below.

Each year the School's program managers assume the difficult tasks of implementing the School's plans earlier adopted for each of our academic programs. In addition, the School's program committees are engaged in ongoing review and assessment of these programs. Finally, our policy committee is charged with overall program evaluation and planning. This year our faculty and students engaged in these processes. They labored diligently and wrought a number of program changes that will surely reflect the substantial expenditure of time and talent devoted to the perennial review and improvement in our academic programs. The committees this year sought not only improvement but stretched for and, I believe, attained some pioneering achievements in program design. The following review of each of our teaching programs describes enough of our academic program activities to capture some of this sense of steady and anticipatory attention that has continued to characterize our faculty's and students' efforts in program planning, implementation, and evaluation.

#### THE UNDERGRADUATE PROGRAM

The first students who have followed the new undergraduate programs from inception to completion graduated with this year's senior class, and the entire undergraduate class is currently operating under the recently revised program.

Since the entire program was restructured and established only two years ago, this year was devoted largely to continued observation and assessment of the program. Several improvements were made in the core subjects and the individual options. It may be helpful to recall that the new curriculum rests on a minimal core of four required subjects followed by five optional career development paths. The core subjects consist primarily of underlying disciplines and techniques common to all areas of management: Managerial Economics and Managerial Psychology, which continue to be well received in their present form; Managerial Environment, which gives the student a perspective on events external to the organization; and Introduction to Management, which focuses on the internal operations of organizations.

I pointed last year to the special problems we had in staffing Introduction to Management effectively and in assuring that it did not become merely a superficial survey affair. After further observation this year,

we decided that Introduction to Management should be replaced next year by a two-term sequence, Information and Decision Systems, which will emphasize the development of skills in problem diagnosis, problem solving, and practical implementation. The purposes of the subject as initially conceived were to (1) teach problem-solving skills in the course of dealing with a variety of management problems; (2) give an introduction to the models and information systems required in dealing with the range of problems covered; and (3) introduce the student to a sufficiently wide array of problems so that he could exercise a more knowledgeable choice in his subsequent selection of an undergraduate Course option. The one-term subject was simply not sufficient to accomplish all of these purposes. We propose further to teach this sequence jointly with the graduate subjects in Information and Decision Systems to help us assess the workability of combined graduate-undergraduate teaching in certain subject areas.

The options following the core consist of four predesigned paths in Behavioral Science, Management Science, General Management, and Dynamics of Management Systems. There is also a special option for the mature student who chooses to design his own study path.

This year the Institute's Committee on Curricula approved Behavioral Science Research Practicum as a subject satisfying the general Institute Laboratory requirement. This is in keeping with the broader view of a laboratory experience which is emerging at M.I.T. The result is that the students of this option now have room in their programs for still more electives to permit them to specialize or broaden their individual courses of study. This research practicum has taken a project orientation. The students this year worked in four groups. One group worked with the administration of the Meadowbrook Junior High School in Newton, Massachusetts, in a combined effort to understand more about the learning process. A second group worked as part-time employees in a supermarket to get a better feel for the organization on which they had earlier gathered substantial research data. A third group is studying the M.I.T. freshman advisory system. The fourth group has been working with black businessmen in Roxbury and in the process members of the group have been testing alternative models of the helping-consulting process. A few of these students are now considering joining VISTA (Volunteers in Service to America) for their first post-graduation jobs.

The General Management option will find itself with a reduction in required subjects with the transfer of the Information and Decision Systems subjects to core requirement status. This now provides the students in this option the opportunity to do more of their own course planning, a curricular thrust in general tune with the times.

The Dynamics of Management Systems option has added a technical writing subject to its curriculum. The purpose is to improve the student's writing abilities as he continues to work in his own special interest area.

The Management Science option also has a project subject for its seniors. Groups work with local firms on operating problems. The purpose is to gain a practical perspective on problems and also to utilize the models they have learned about in their formal subject work.

It is difficult to evaluate the success of the program in the context of the current Selective Service situation. Many post-graduation positions may be chosen for reasons other than career interest. The information which is available indicates that our graduates are attractive to graduate schools and to high-quality hiring firms.

One important improvement resulting from the new program is to be found in the quality of our faculty counseling for undergraduates. Instead of the traditional pattern of assigning students to registration officers on an alphabetic basis, faculty counselors were chosen for each option based on their teaching and research interests in that field. This has generated closer relationships between student and counselor and resulted in more professional counseling. Those responsible for this improved counseling are Professors Thomas J. Allen, Irwin M. Rubin, Glen L. Urban, Stewart C. Myers, Christopher R. Sprague, Jay W. Forrester, Billy E. Goetz, and David Durand. We have not yet, however, fully resolved the problems of providing enough counselors and maintaining continuity of counseling. We have only one official counselor for each program and two may be necessary to avoid large numbers of students per counselor and to help alleviate the disruptions in continuity that occur when a counselor leaves, or takes a sabbatical year, and so on. It is not clear how we can meet this problem easily in the face of the many other demands on faculty time — including the extensive demands for the proper counseling of Master's and doctoral students — but we must make every effort to do so. In this regard, Professor Goetz, who retired this year, will be missed as the counselor for students following special programs. His guidance and insistence on thorough analysis of objectives, careful planning, and adequate consultation have been great strengths in ensuring the design of meaningful programs for the small but important number of students electing this option.

The undergraduate program model of a minimal required core of subjects, followed by a number of career options with improved option counseling, continues to gain acceptance in our Master's program and, indeed, in the Institute as a whole. It gives the student increased choice of study paths but with enough guidance to steer him between the Scylla of an incapacity to act at all, as a consequence of his finding him-

self overwhelmed by the many choices afforded in our fuller menu, and the Charybdis of an inappropriate choice of subject combinations.

#### THE MASTER'S PROGRAM

The effect of the Selective Service on our Master's Program this year was not as great as we had anticipated. Enrollment was slightly lower than the average of the past five years, but not enough to change the number of class sections, and the quality of entering students continues to be high. We granted 87 degrees during the academic year, just one fewer than last year. We scheduled about 120 company recruiting visits at the Sloan School, and we have observed a sizable increase in the salaries offered to our graduates. We do not have final reports yet for 1969, but it appears that the median this year may run more than \$1,500 above last year's annual salary offer. It is quite evident that our graduates have a great deal of talent and training to offer to employers.

The number of applications received so far for 1969-70 admission has passed the 675 mark, and we are likely to receive more before the end of the summer. Whether the increase has been caused by our recruiting efforts we do not know.

The experimental student recruitment program begun last year was continued this year and expanded to include several black colleges. In addition a program to recruit black students is planned for the fall of 1969.

Table I summarizes a profile of this past year's entering class, and Tables II-IV summarize and elaborate some of the trends and indicators I have just noted.

The Master's Program Committee (whose membership has been augmented by two representatives from the student body) has met frequently to discuss objectives and design of the curriculum. As a result of suggestions by student members, plans have been made to experiment further with student planning of a graduate elective as an extension of the participation of students in 15.201, Management Environment, this past year. After having offered 15.092, Mathematics for Management II, this past year as an elective, the Committee has decided to reinstate it as a requirement. (The majority of the first-year class elected it; the others lacked the background in linear programming required for 15.502, Information and Decision Systems II, and had to acquire it by independent study.) Further progress is planned in the integration of 15.501 and 15.502, Information and Decision Systems I and II, with the intention of making the sequence a fourth discipline (systems analysis) in the required curriculum.

**Table I Profile of Master's Class**

Personal background	
Sex:	Males 94 Females 3
Age:	Median 23 Range 21-34
Marital status:	Married 27 Single 70
Academic and work experience	
	Full-time work experience 37
Admission Test for Graduate Study in Business (A.T.G.S.B.)	
All applicants	Entering class
Median 567	Median 609
Range 246-764	Range 246-745
Undergraduate grade point average	
All applicants	Entering class
Median 3.9	Median 3.9
Range 2.4-4.9	Range 2.8-4.7
Undergraduate major	
Engineering	40%
Science	19%
Business	28%
Other	13%
Undergraduate Schools	U.S. 37 Foreign 20

**Table II Indicators of Academic Quality  
Students Entering Sloan School Master's Program, 1963-68**

Academic year	Size of entering class	Class median, percentile score, A.T.G.S.B.*	Class median, undergraduate cumulative average**
1963-64	98	N.A.	3.9
1964-65	88	N.A.	3.8
1965-66	108	94	3.8
1966-67	102	95	3.9
1967-68	106	89	4.0
1968-69	97	92	3.9

\*Admission Test for Graduate Study in Business

\*\*Cumulative Quality Point Average, 5.0 = A

**Table III Starting Salaries of Sloan School Master's Program Graduates  
1961-69 (dollars per month)**

	Year of graduation								
	1961	1962	1963	1964	1965	1966	1967	1968	1969*
High	930	2,000	2,000	1,250	1,055	1,350	1,250	1,500	1,750
Median	660	683	712	750	820	890	958	1,015	1,170
Low	450	525	490	583	650	650	600	656	792

\*Based on incomplete returns (about 75 per cent of expected total)

**Table IV Estimated Master's Employment Data**


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<i>Categories:</i>	
Operations research and computer staff	25%
Consulting	14%
Management	14%
Financial analysis and planning	12%
Engineering	6%
Other (including government, military, teaching)	29%

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*Industries:* The consulting industry hired the most graduates, followed by petroleum. IBM hired the most graduates; there was a wide range of companies represented including banks, aerospace firms, stock brokers, and auto manufacturers.

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In this first year of requiring each Master's candidate to select a concentration option, we have found the largest numbers choosing the fields of finance, international business, management information systems, and organization studies.

Professor Arnold E. Amstutz has continued his research project on the Master's Program and has accumulated further extensive statistics to be used as subject and program evaluation measures by the faculty and administration.

The Master's Program Committee has continued to seek a distinctive tone for our Master's Program, as well as to aim for the distinguished levels of admissions standards and degree candidate attainments referred to a moment ago. Faculty and students have continued to learn more about the School through our "self-study" project and to experiment with the teaching and learning process. The main substantive emphasis is still on problem structuring and solution through a "systems analysis" process. The Program's format remains flexible after last year's efforts to minimize rigidities. The Master's Program Committee has recommended that we implement an "applied management program" (a variant of a cooperative work-study program) as an experimental option for a small number of our incoming students. This proposed experimentation suggests that we will continue to strive for the greatest motivation to teach and to learn which we can muster in both our faculty and our students engaged in this program.

#### THE DOCTORAL PROGRAM

The faculty of the Sloan School in 1968-69 adopted an entirely new Ph.D. Program which will go into effect in the coming year. A number of proposals for Program reform were made by the Ph.D. Program Com-

mittee during the year, principally in three successive memoranda. The faculty considered these memoranda both individually and collectively, first by making specific proposals for changes in content and emphasis in written responses, then by lengthy and detailed discussions of the proposals in their entirety in open faculty meetings. The present student body of Ph.D. candidates provided detailed criticism of the memoranda, and made up alternative programs of reform. A lengthy questionnaire was sent to each student presently enrolled in the Program, and the responses received from two-thirds of the students provided a substantial basis for revisions in the last draft of the new Program memorandum.

The Program adopted shows a decided departure in emphasis on various performance indicators on the Ph.D. candidate. There is much more emphasis in the new Program on research output, and on teaching, and much less emphasis on grades and examinations in required subjects. It is proposed that the candidate complete a major article-length research study before taking general examinations, and that more student and faculty resources be put into the first stages of thesis production. The new Program also strongly recommends that each candidate teach in the Sloan School in "apprenticeship" with a senior faculty member. He could, if he chose, help in preparing subjects in his area of interest after he has completed general examinations.

There are no subject requirements in the new Program; rather, the student is required to complete "part one examinations" in the discipline areas of economics, behavioral sciences, and applied mathematics, and "part two examinations" in major and minor fields of his choice.

The new Program will begin with offerings of part one examinations in September, 1969. Those students with advanced degrees and experience might well be expected to pass them on entry, so that they can begin preparation for part two examinations. Those without previous graduate work will be offered Ph.D. seminars in the three basic disciplines, which will presumably move them on to successful completion of part one examinations in the spring of 1970. Part two examinations are expected to be given to each candidate after at least one year of preparation subsequent to part one examinations. Part three consists of the work done in relation to the thesis and the "teaching apprenticeship." It is expected that all three parts will take no student more than three years to complete and that those students with advanced preparation can finish the degree Program in two years.

The Ph.D. Program Committee, in response to the suggestions of the faculty and students to their various draft proposals, spent more than one collective man year on preparation of the final Program. For the first time the committee included two student members who were elected by



the presently enrolled Ph.D. candidates. These members, Charles Y. Gibson and Thomas P. Gerrity Jr., made substantial contributions to the design of the new Ph.D. curriculum, principally by conducting and evaluating the detailed questionnaire sent to all of the Ph.D. students and by supplementing the results of this questionnaire with personal discussions with the students. Mr. Gerrity and Mr. Gibson also contributed to the selection of newly entering candidates and the evaluation of the petitions and other general requests made to the committee throughout the year.

The selection of 20 new candidates to enter this fall took place while the new Program was in the process of being designed. Some attempt has been made by the Committee to design methods to compare the performance of the candidates under the new Program with that of candidates who entered under the old Program, in order to test the "long-run effectiveness" of reform. A small grant from the Sloan School research funds has allowed the collection of detailed information on the presently enrolled candidates to serve as a basis of comparison with those enrolled in the new Program.

A look at the last academic year shows that the Ph.D. Program has taken on new objectives and ways of achieving these objectives. It remains to be seen, in the coming years, whether they can be achieved. But it is the consensus of the faculty and student body that the promise of the new Program is exceptional, and the opportunities it offers for gaining experience in research and in developing new concepts in management are very great.

Tables V and VI summarize some of the basic facts concerning this year's entering Ph.D. class, trends in admission applications, entering class sizes, total enrollment, degrees granted, and employment data for the program.

#### THE ALFRED P. SLOAN FELLOWS PROGRAM

The largest class of Sloan Fellows (50) received their Master of Science degree in management on June 13, 1969. It was the 38th class to complete the Program and the 31st class to be identified as Alfred P. Sloan Fellows.

The Program is increasingly enriched by the imaginative experimentation of the faculty. Two such innovations bear special mention: (1) An attempt was made to interrelate industrial dynamics, operations management and management information systems under one broad umbrella (Information and Decision Systems). The results were more successful than other attempts in the past, but more work is still required to coordinate the unique contribution of all three areas. (2) The introduction in the fall term of International Business by Professor Charles P. Kindleberger

**Table V Profile of Ph.D. Class**

<b>Personal background</b>	
Sex: Males 18 Females 1	
Age: Median 25	
Range 21-36	
Marital status: Married 12 Single 7	
<b>Academic and work experience</b>	
Full-time work experience 13	
<b>Admission Test for Graduate Study in Business</b>	
All applicants	Entering class
Median 598	Median 661
Range 253-780	Range 487-780
<b>Undergraduate grade point average</b>	
All applicants	All admitted
Median 4.0	Median 4.3
Range 2.6-4.9	Range 3.2-4.9
<b>Undergraduate Major</b>	
Engineering	20%
Science	20%
Business	10%
Economics	25%
Other	25%
<b>Undergraduate schools</b>	U.S. 13 Foreign 5

**Table VI Ph.D. Employment Data**

Nine Ph.D. recipients went into teaching at the following schools:

McGill University  
 Sloan School of Management  
 Wharton School of Finance and Commerce, University of Pennsylvania  
 University of Southern California  
 Manchester (England) University  
 Case Western Reserve University  
 University of California at Berkeley

Other Ph.D. graduates accepted positions at the International Bank for Reconstruction and Development and with a mutual fund.

of the Department of Economics and Dr. Richard D. Robinson was received with great enthusiasm by the Sloan Fellows. This vital area, drawing heavily on international economics and international management, will become a regular, required part of the curriculum.

More time than ever before was allocated this year to the study of problems faced by municipal and state governments. Each year, for the past four years, an increasing amount of time has been devoted to seeking a deeper understanding of civil rights, fair employment, issues in education, and the responsibilities of private industry to the community. Typically, the approach has been to hold informal, off-the-cuff meetings with officials like the Mayor of Boston, the Governor of Massachusetts,

the Attorney General, and state senators. This year, those meetings were extended to include leaders of the black community and senior business executives concerned specifically with civil rights and fair employment. As the complex problems of the cities press harder for solutions, additional time will be spent analyzing those problems in a more systematic manner.

An evaluation committee analyzes every facet of the Program throughout the year and it reports its findings and recommendations to the Director of the Program. The Chairman of the Committee is Charles A. Myers, Sloan Fellows Professor of Management. The work of the committee is an invaluable contribution towards the School's attempt to maintain the highest possible standards of excellence.

The selection of the class of 1969-70 was completed on March 30, 1969. Once again the number of applications set a new record and the selection decisions were difficult. The new class will bring some welcome firsts: two managers from the Soviet Union (both from the Institute of Automatics and Telemechanics); two members of the black community; the first manager to be nominated by a city; the first newspaperman (the Industrial Editor of the *London Times*); and the first manager of an elementary school system.

A number of organizations will be represented for the first time: Baird Chemicals, Cabot Corporation, Canadian Government, City of Atlanta, Delta Airlines, General Cable, Gulf Oil, Institute of Automatics and Telemechanics, La Telemécanique Electrique, *London Times*, University of Montreal, Whirlpool Corporation. We welcome back to the Program those organizations that have been absent for two or more years: Campbell Soup, Consumers Power, Continental Can Company of Canada. The class of 1969-70 will be the largest in the history of the program (52).

As the field of management develops a larger and more universally applicable body of knowledge, it is expected that participants' careers will exhibit a richer variety. Sloan Fellows from industry and the Federal government will share the study of new concepts with those who manage hospitals, cities, school systems, and universities. Such a diversity of interests cannot help but make the Sloan year a richer experience for the Fellows and for the faculty.

A first step towards an interesting experiment is reflected in the new class. An attempt was made to recruit several nominees from one city so that they would return to that city and reinforce one another as they set about putting their new-found knowledge to work. Those who attend the Sloan Program tend to form close and meaningful ties at M.I.T., but they disperse at the end of their 12 months of study. It was felt that if a small group of men were to come from the same city and

return to that city after completing the Program, they would continue to work closely together to the benefit of their sponsoring organizations.

They might even contribute more of their time, in a coordinated manner, to the problems of their own community. Atlanta, Georgia, was chosen as the first city for the first leg of the experiment. Atlanta is a progressive city, amenable to experimentation, and neither too large nor too small. Three men will come from Atlanta, representing the following organizations: the City of Atlanta, Delta Airlines, and Lockheed-Georgia. The men are not obligated, formally or informally, to any program or activity when they return; however, based on past experience, they will probably continue to maintain the close ties the Sloan Fellows form at the Institute. The experiment will be continued the following year — either in Atlanta, or in another city.

The accompanying table summarizes some of the vital statistics for this year's and next year's Sloan Fellows Program.

**Table VII Alfred P. Sloan Fellows Program**

	Current year 1968-69	Next year 1969-70
Enrollment	50	52
Age range of Fellows	26-47 years	30-44 years
Average age of Fellows	36.8 years	36.0 years
Fellows with M.I.T. degrees	5	2
Fellows with Master's degrees	15	11
Fellows with doctorates	0	2
Companies and organizations represented	47	44
Industries represented	25	24
Foreign countries represented	7	5
Number of foreign Fellows	8	8
Nationalities	American, British, Canadian, French, Japanese, Norwegian, South African, Venezuelan	American, British, Canadian, French, German, Russian

#### THE PROGRAM FOR SENIOR EXECUTIVES

The enthusiasm, on the part of industry, for this particular Program is reflected in the ever-increasing number of applications. Some applications for 1971 and 1972 have already been received. The number of applications from abroad continues to increase at an even faster pace. To date, the largest number of foreign applications comes from the United Kingdom, Canada, Australia, and Scandinavia — then Italy and France, in that order. More recently, applications have started to come in from Taiwan, South Korea, and Japan.

The trend described in last year's report continues, and it is expected to continue; that is, the typical participant will tend more and more to be a university graduate, often with a Master's, or even a doctoral degree,

usually in a technical field. He will be younger and he will be increasingly interested in and knowledgeable about a wider range of sophisticated quantitative methods of analysis. The men who attended the fall 1968 and the spring 1969 sessions included 13 Master's degrees and five doctorates.

There were nine foreign countries represented in the spring 1969 session, compared to two in the fall 1968 session. This was an unusually large number and, in all probability, will not reach that level again. However, the foreign participants seem to add a great deal to the program. The men from abroad tend to carry more senior positions and, by and large, they come with a voracious appetite for knowledge concerning modern management.

An evaluation committee has been formed, under the chairmanship of Professor Zenon S. Zannetos. The committee is charged with analyzing every dimension of the Program and to report its recommendations to the Director of the Program. Although the Program's popularity continues to increase, the committee, under the able leadership of Professor Zannetos, should help the Director of the Program to shape this School activity to allow it to provide substantial challenge and intellectual development not only to the participants, but to the faculty as well.

A special note should be made here to recognize some important curriculum developments made by Professors Wallace B. S. Crowston, Jay R. Galbraith, and David N. Ness, in the M.I.T. Program for Senior Executives. Those three members of the faculty have integrated their own contributions and they have attempted to bring in other disciplines, in such a way as to present some exciting team-teaching in an interrelated, coordinated manner. The results have been rated very highly by the participants. There are some important extrapolations of these efforts to other programs, such as the Sloan Fellows Program.

A brief profile of this year's Senior Executive classes is outlined in the following table.

#### THE M.I.T. PROGRAM FOR URBAN EXECUTIVES

From January 5 to 31, 1969, 21 senior managers from 18 municipalities attended a new four-week Program offered by the Sloan School, with the help and assistance of the Urban Systems Laboratory, plus individuals and groups from various faculties: the Schools of Engineering and Science, and the Departments of Economics and Political Science.

The objective of the Program was to help develop key managers who influence the design and the implementation of municipal policy. The curriculum consisted primarily of management subjects. The remainder of the curriculum included a series of presentations, dealing with recent

Table VIII M.I.T. Program for Senior Executives

	Fall 1968	Spring 1969
Enrollment	27	26
Age range for Senior Executives	41-51	34-51
Average age of Senior Executives	45.2 years	45.4 years
Senior Executives with M.I.T. degrees	1	2
Senior Executives with Master's degrees	5	8
Senior Executives with doctorates	2	3
Companies and organizations represented	26	26
Industries represented	11	15
Foreign countries represented	2	9
Number of foreign Senior Executives	5	9
Nationalities	American, British, Italian	American, British, Australian, Chinese, Swiss, Swedish, French, German, Canadian

developments in technology, having specific relevance to urban issues and to the problems involved in the effective transfer of technology to urban problems.

The Program was designed and administered by the Sloan School.

At the end of the Program, the participants recommended unanimously that the program become a permanent offering of the Institute. It has been decided to present another such Program from June 15 to July 11, 1969, in order to help arrive at a decision as to whether such a Program should indeed be given on a regular and continuing basis.

#### GREATER BOSTON EXECUTIVE PROGRAM (G.B.E.P.)

There are now nearly 300 alumni of this unique Program, and the alumni are spread throughout more than 30 organizations in the Greater Boston area.

The Program continues to attract a large number of applications for the 25 places available each year. The class that completed its studies on May 16, 1969, included 19 different companies.

Perhaps the characteristic of the Program that most quickly comes to mind is the enthusiastic appreciation of the participants. The attendance record is remarkably good and the yearly alumni reunions bring back more than 50 per cent.

This unique contribution of M.I.T. to the community within which it works must be measured in terms even larger than the education it is providing to the business members of that community. The Program opens a relevant part of the Institute to an important sector of the community. For the G.B.E.P. participants, the Institute is no longer an impersonal giant providing mysterious services to far-away clients. It is a useful, contributing member of its own community.

#### SUMMER PROGRAMS AND INDUSTRIAL LIAISON PROGRAMS

In order to implement our policy of offering continuing education to individuals no longer participating regularly in the academic community, members of the faculty of the Sloan School again this year gave several short Programs in the Summer Session and contributed to the Industrial Liaison symposia.

Professors Forrester, Edward B. Roberts, and Carl V. Swanson, with Alexander L. Pugh III, and other members of the industrial dynamics group of the School, offered their Program, Industrial Dynamics, in which each participant had the opportunity to build his own dynamic model and test it on M.I.T.'s on-line time-sharing computer system.

Professors G. Anthony Gorry, Ness, and Sprague offered a new Program, Management Information Technology, designed to give operating

managers an understanding of the nature of digital computer systems and their relevance to information processing. Although complete in itself, it gave participants an excellent background for the Program, Management Information Systems, offered by Professors Donald C. Carroll, Michael S. Scott Morton, and John F. Rockart of our faculty and Professor James C. Emery of the Wharton School of Finance and Commerce at the University of Pennsylvania. Managers attending the latter program acquired an appreciation of the potential of computer applications and their economic and organizational implications.

Professor Jeremy F. Shapiro gave a two-week Program, Mathematical Programming, which dealt with the formulation of models from practical problems and their solution, as well as the theory of linear, nonlinear, and integer programming.

Professor Galbraith directed a Program, Operations Management, which gave operating managers decision-making techniques for topics such as production scheduling for seasonal sales, job shop scheduling, inventory control, and facilities planning. Lecturers included Professors Carroll, Crowston, John F. Pierce, and Leon S. White, all of the Sloan School.

Systems Analysis for Marketing Management was designed by Professor Amstutz to acquaint managers with systems analysis as a tool for market planning and control. Workshop sessions gave participants an opportunity to design and evaluate prototype market planning and decision systems using the M.I.T. Compatible Time-Sharing System (CTSS).

Professors David B. Montgomery and Glen L. Urban offered Management Science in Marketing, presenting recent advances in the application of management science to marketing, with applications in all areas of marketing. Professors Amstutz and John D. C. Little of the Sloan School and Professor Irwin Gross of the Wharton School of Finance and Commerce at the University of Pennsylvania were lecturers in the program.

Management of Research and Development, directed by Professors Donald G. Marquis and E. B. Roberts, assisted by other members of the M.I.T. faculty and staff, used a combination of problem-oriented workshops and lecture sessions to give managers an understanding of organizational systems analysis and design and an appreciation of human relations concepts and practices.

Professor James S. Shulman (Visiting), with the assistance of other faculty and practitioners competent in the area, offered A Design for Strategic Planning, with the objective of guiding management in formulating and implementing organizational strategy by identifying the variables that must be considered in analyzing business situations and designing courses of action from the point of view of top management.



Members of the Sloan School faculty also participated in the Industrial Liaison Office programs for participating corporations. Professor Zannetos was chairman of a symposium, "Management Information and Control Systems," in November. Professors Amstutz, Carroll, and Scott Morton also took part in the program. In March Professor Edgar H. Schein presented a symposium at Los Angeles, "The Management of Human Resources."

#### THE SLOAN SCHOOL'S TEACHING PROGRAMS IN PERSPECTIVE

The distinctive aspects of our several teaching programs and the unitary elements common to these programs have both come to sharper focus during the past year.

The substantial revision of our Doctoral Program has been largely responsive to the very careful assessment made by our faculty and students of the different attributes and career goals of a "typical" doctoral candidate as distinguished from the "typical" Master's Program candidate. Our introduction of a new Program for Urban Executives was similarly a recognition of some important distinctions in the target audience of this Program as distinguished from the middle and senior managers who come to our Sloan Fellows or Senior Executive Programs from commercial or industrial environments.

At the same time we have pressed forward in our efforts to cement the School's academic programs wherever the procedural or substantive issues warranted such unification efforts. We have, for example, continued to make good progress in fashioning from four functional fields what is essentially a new disciplinary strand, Information and Decision Systems, which we now offer in each of our programs. There has been a discernible and, I feel, effective effort this year to transfer to our Executive Development Programs some of this coordinated and interwoven systems subject from the undergraduate and the Master's programs in which the linking efforts had begun two years ago.

There are still problems evident in our program design and we are seeking to remedy these. We continue to seek improved coordination of our many talents, where such combined effort of faculty in two or more "traditional" discipline or functional areas promises to yield an improved older or more desirable newer product. Intramurally, we continue to clarify for ourselves the distinctive purposes of our several Sloan School programs. Extramurally, we seek to provide a measure of uniqueness based on our own special combination of talent, resources, and *Weltanschauung* for each of our own programs vis à vis similar programs offered at other major universities.

We are continuing to expand our enrollment of black and other dis-

advantaged minorities' students in an effort to increase the flow of such individuals into important managerial or entrepreneurial positions. We worked hard last year at recruiting both men and fellowship dollars to help us in these efforts. We have also made some efforts to develop genuinely custom-tailored study-research programs for a small number of individuals whom we enrolled as full-time special fellows after extended discussions in each instance concerning the mutual profitabilities of such career development and educational undertakings.

We have also begun to speculate about the variety of formats we might add to those we already have crafted in our efforts to make available to our alumni and to other postgraduates the opportunity to continue learning after a first degree.

I concluded this section in last year's report with the caveat that changes and perhaps even choices in program offerings or emphasis must be the inevitable consequence of the limited financial and manpower resources available to us for our academic programs.

We have not yet had to curtail any ongoing teaching program or piece of a program to free up resources to permit us to add new programs or to increase the allocation of resources to some other ongoing School program. But it is clear that we have been conscious of our budget constraints, and we have adopted to date two strategies to help us cope with this problem. We have first, as I have just noted above, made every effort to coordinate and link teaching efforts for different programs where such efforts have been deemed reasonable and even desirable. Second, we have begun to experiment in a few areas with new self-learning or student teaching methods which rely more heavily on self or peer class time and use the scarcer faculty talent as consultants or resources to be tapped as required.

The basic challenges of choice and change remain but we have in a year moved closer to exploring the variety of effective organizational and design responses to help us deal wisely with this persisting task.

#### RESEARCH IN THE SLOAN SCHOOL OF MANAGEMENT

As a leading graduate school of management, we are continually pressing forward in our search for new areas of knowledge relevant to industrial management, and to other applications of management in education, public affairs, and medical services. This new knowledge is fed back into our curriculum, so that our teaching is continually enriched by our research. A number of graduate students participate in research programs as research assistants.

The summary which follows cannot give the full flavor of the variety of significant research in which our faculty is engaged. Working papers, journal articles, monographs, and books provide accounts of projects

partially or fully completed, as do occasional programs for the Industrial Liaison Office or at Special Summer Session Programs. Many studies are in progress or just getting under way. The following review is by discipline and functional classification. But these groupings do not reveal the full range of interdisciplinary research which has been spreading at the School. Many problems in management, especially in the newer areas, defy compartmentalization.

#### THE HUMAN FACTORS IN MANAGEMENT

Three interrelated fields — organizational behavior, the management of science and technology, and industrial relations — comprise a continuing important research area at the School.

**ORGANIZATION STUDIES** Under the leadership of Professor Mason Haire, research is continuing on the construction and implementation of models for manpower movement within the firm. With the cooperation of Professor Alan L. Patz, this research will now be taken into the field for implementation in a number of firms. Professor Patz has also been developing some working papers applying management science techniques and organization theory to the problems associated with manpower or human resources management. Professor Haire has also been examining the role of behavioral science consulting firms in the transmission of technology from universities to users in the business and wider community. Professor Schein has continued his research on the way a new arrival learns the value system of an organization. Selected departments at M.I.T. are being studied, in addition to the Sloan School. Professor David A. Kolb is bringing his research on self-directed behavioral change together in a book, and he has begun research on entrepreneurship in the inner city as well as on the socialization of M.I.T. freshmen (the latter with Professors Schein, Rubin, and George F. Farris). The objective is to develop new methods of orientation, selection, and training which prevent oversocialization and stimulate active creativity. Professor Rubin is also concluding a research project (with two former colleagues) on the roles of M.I.T. Fellows in Africa in the national organizations with which they worked, the processes through which contributions were made, and changes in the attitudes, values, and goals of the Fellows. Professor Farris has been studying ways in which leaders react to past performance of their groups, and how this reaction affects the way the group works together in making decisions. Associate Dean Peter P. Gil is undertaking an evaluation and analysis of management development programs in a selected group of industrial firms, with subsequent plans for a symposium of company presidents to review and discuss the research findings. He is also evaluating the M.I.T.

Program for Senior Executives through questionnaires to eight separate alumni groups.

**MANAGEMENT OF SCIENCE AND TECHNOLOGY** A related major area in organization studies is under the leadership of Professor Marquis on the organization and management of science and technology. Current research is centered around the development of new technological ideas and their utilization. Studies are being made of the characteristics of those involved in this process: Ph.D. scientists, inventors, and research directors. In another study, award-winning innovations in a scientific institute are being compared with commercial inventions in a firm, with respect to factors involved in the process and the channels and sources of information. Professor E. B. Roberts has continued his studies in new enterprise management, particularly those spun off from scientific and engineering research. Professor Allen's research is centered on the information needs of engineers and scientists, particularly within and among research and development laboratories. Professor Farris is completing his study on the factors affecting the turnover of technically skilled personnel. A full review of the last two years' research in the management of science and technology is available in a separate report written by Professor Marquis.

**INDUSTRIAL RELATIONS** As the separate report of the Industrial Relations Section by Professor C. A. Myers points out, the group in this area turned its research efforts several years ago to the manpower aspects of urban problems. Before he took a leave of absence to serve as special assistant to Secretary of Labor George P. Shultz, Professor David P. Taylor continued his study of the company relocation and manpower impacts of the Kendall Square Urban Renewal Project, in collaboration with Professor Francis M. McLaughlin (on leave from Boston College). With Professor Michael J. Piore of the Department of Economics, Professor Taylor also examined the experience with subsidized on-the-job training programs in three occupations: tool and die making, offset printing, and restaurant work. Professor Douglass V. Brown, who is president-elect of the Industrial Relations Research Association, has continued his work on legalism and industrial relations in the United States. Professor D. Quinn Mills is involved in a number of related studies of manpower in the construction industry, including manpower utilization, wage behavior, impact of Federal housing policy, and manpower development in the industry. Professor Abraham J. Siegel has edited and written the introduction for a forthcoming M.I.T. Press book on the impact of computers on collective bargaining; and Professor C. A. Myers has nearly completed a working

paper on the impact of computers on certain knowledge-based industries such as education, libraries, legal and legislative services, health and medical services, and national data banks. The Section completed and published a study by Frazier Kellogg, an earlier research associate, on computer-based aids to the placement process, and Dr. Jon M. Shepard, research associate during the past year, is completing a comparative study in industry and in offices of the impact of mechanization and automation on work attitudes.

#### MANAGEMENT ENVIRONMENT AND POLICY

This area includes research in three related fields: economics, finance, and other aspects of business policy.

**ECONOMICS** Professor Paul W. MacAvoy is engaged in a study of the economic, financial, information, and control aspects of the Federal Power Commission as an independent regulatory body. His objectives are to provide evidence of the economic effects of regulation, to suggest restructuring to improve the current level of achievement, and to construct control systems to reduce the cost of regulation to the government. Professor Lester C. Thurow has three research projects under way: an investigation of changes in the distribution of income in the United States; an intermediate-run fiscal planning model; and (in association with Professor Edwin Kuh) the economic effects of large-scale housing programs. Two books by Professor Thurow, *The Economics of Poverty and Discrimination*, and *Investment in Human Capital*, were published earlier in 1969.

Professor Kindleberger of the Department of Economics now has a joint appointment in the Sloan School to work in the area of economics of international business. He organized a series of spring seminars with visiting speakers on the international corporation, and a book will be published with these papers. He is also working on a book, *Economic Perspective in International Relations*, which focuses on the relationships between economic, political and social activities, including devaluation and international trading agreements.

**FINANCE** Some of the research in this active area necessarily overlaps with economics. For example, Professor Kuh has been developing a medium-sized macro-economic model of the U.S. for forecasting and teaching purposes, and he continues his association with the Econometrics Project funded by the National Science Foundation (NSF). Professor Franco Modigliani has devoted considerable time to the development and use of the M.I.T.-Federal Reserve Board model, which is used for diagnostic simulations and to study the working of major tools of stabili-

zation policy, both fiscal and monetary. Professor Daniel M. Holland has been investigating the effects of taxation on corporate executives, with particular attention to their attitudes toward output of effort, acceptance of promotion, choice of job, and desirability of stock options. He is also examining the Federal role in local fiscal policy in older metropolitan areas which suffer from declining taxable capacity coupled with an increase in welfare requirements.

Professor Paul H. Cootner's main research continues to be on optimum portfolio theory and policies for intermediaries, such as banks, insurance companies and pension funds. He is also working on a study, with Professor Franklin M. Fisher in the Department of Economics, of commodity hedging and speculation in the world copper market. Professor C. Myers has been developing linear programming models for long-term financial planning, and has continued his study of conglomerate mergers. Professor Gerald A. Pogue is involved in an empirical evaluation and application of a model for equilibrium in the capital markets and, with Professor Myers, on the development of an application-oriented model for long-range financial planning. Professor Scholes is testing a capital asset pricing model to determine whether it can explain the relationship between the structure of asset prices and the inherent risk.

**OTHER ASPECTS OF THE BUSINESS POLICY** Professor J. Daniel Nyhart is completing his study of the global structure of development banks and development banking systems, and has supervised the research on the Brazilian development banking system. Parts of this research have involved Professor Farris, who is making comparative studies of attitudes, values, and organization planning in the banking system, and Professor Paul E. Roberts, who is developing a cost-benefit accounting system. One objective of the entire project is to determine if anything can be learned about the transmission of management techniques to a developing country. Dr. Robinson is engaged in a number of studies in the international business field, particularly on international mixed ventures, and on the impact of Canadianization on the structure and policies of U.S. firms. Professor Michael J. Brower is completing a study on business and economic development in Colombia, where he spent a year. Professor Thomas M. Hill, from the management information systems group, has been completing a joint evaluation of the institution building process as found in the new Indian Institutes of Management in Ahmedabad and in Calcutta (which he helped the Sloan School to establish with Indian colleagues several years ago). Mr. Richard S. Morse has been concerned with entrepreneurship and innovation in large corporations, and with the growth and acquisition of small enterprises.

MANAGEMENT INFORMATION AND DECISION SYSTEMS

Research in the areas of management information and control systems, industrial dynamics, marketing, operations management, operations research, and quantitative methods continues to be a distinctive feature of the School's activities.

MANAGEMENT INFORMATION AND CONTROL SYSTEMS Professor Zannetos is studying the sensitivity of management decisions to quantitative models, and methods for improving the efficiency of such models through management information and control systems. This research is with the Army Materiel Command. Another research project of Professor Zannetos is with the National Aeronautics and Space Administration (NASA), on the application of planning and control mechanisms to large projects, starting with the translation of objectives into meaningful goals, down to the lowest planning level. Professor Scott Morton has continued his research on the design and use of an interactive visual display system for management decision making. Professors Zannetos and Scott Morton have also had a major part in the research project on the management of education mentioned below. Professor Rockart's research has been in the medical services area, also discussed below. Professor Malcolm M. Jones, with major responsibility for the work in M.I.T.'s famous Project MAC, is doing research in on-line simulation on a time-sharing system, and is also performing experiments on Project MAC to see whether a totally integrated management information system for budgetary control, project scheduling, accounting, personnel decisions, and many other functions can be performed from a single data base. He is also examining the problems of running a large-scale software project. Professor Ness has been working on a system for enabling different computers to be programmed in one language, and on providing structural flexibility for budgeting models on time-sharing systems. Professor Sprague has been doing research on the so-called "traveling salesman" problem, using linear programming and a branch-and-bound technique. Professor Pierce has been working with him on this problem.

INDUSTRIAL DYNAMICS Professor Forrester has directed his attention during the past year to a study of urban dynamics, in order to understand the reasons for deterioration in aging urban areas. The system study was aimed first at understanding the process, then it was used to explain why most of the efforts in the past three decades to cope with urban problems have failed. Finally, it has attempted to point the way toward some quite different policies which might generate revival in stagnated city areas. A book on this research was published in May by The M.I.T.

Press. Professor Swanson has been involved in two main research areas: a study in growth dynamics showing how a common resource control policy can foster fluctuation and/or retard the growth of a firm, and a management control system design using industrial dynamics. Mr. Pugh has continued his work on the DYNAMO compiler, used in industrial dynamics systems. Dr. Dennis L. Meadows's research on the dynamics of commodity fluctuations has been completed this year and the first stage of this work will be published as a monograph.

**MARKETING** Professor Little's research is centered on models for media planning, looking at the reasons for the use of a model which works in some cases but not in others. Professor Little is also working on adaptive control systems in marketing, and on an on-line information model for a product manager. Professor Amstutz has been developing a macro-analytic simulation of market interaction based on precise quantitative behavioral theory. He has also directed his attention to the influence of top management on the design of marketing information systems and their subsequent utilization. Professor Montgomery has revised a previously formulated dynamic sales call policy model to provide for more convenient input of data and for management judgment. It is currently being tested in the Boston area. With Professor Alvin J. Silk, he has been studying the effect of the influence of other persons on consumer purchasing and consumption behavior. In a separate study, they are also developing and estimating econometric models of market response. Professor Silk has been doing an experimental study of the effects of pleasant and unpleasant radio commercials, and (jointly with colleagues at other universities) a study of the effects of consumer advertising on the retail availability of a new product. Professor Urban's research is on new product selection and promotion, geographical allocation of advertising expenditure, and management science and family planning.

**OPERATIONS MANAGEMENT** Professor Carroll, on leave during the past year, has continued his research on the potentialities of on-line simulation in real-time management. Professor Crowston has been working on an interactive visual display system for decision making on engineering design changes in a large aircraft company. He also has a number of research projects under way, including programming and testing of algorithms in handling the quadratic assignment problem, a variant of the critical path method, decomposition and solution of decision networks, and the use of network algorithms to solve certain types of integer programs more efficiently. Professor Galbraith is studying specialization and differentiation of subtasks in high technology projects (in the large air-



craft company), and is continuing his work on a motivational model to explain the differences in output performance among operative workers. Professor Galbraith's research overlaps significantly with that in organizational behavior, and he has also worked with colleagues in that group. Herbert F. Goodwin is concerned with the implementation of new management techniques, and ways of inducing more positive top management response. Professor William A. Martin has worked with others on the development of PRISM, a computer system that permits students to interact with the computer in problem solving and then examine the actions of the class in its use. In addition to working on the "traveling salesman" problem, Professor Pierce has centered his research efforts on solving the integer stock cutting problem, to minimize wastage created by taking several different-sized sets from a standard size of stock. Finally, Professor Goetz has completed revisions of three books on management planning and control, quantitative methods, and accounting in action.

**QUANTITATIVE METHODS** (not otherwise reported) Professor Gordon M. Kaufman is working on a mathematical methodology of statistical decision theory. This includes inference and decision problems from a Bayesian viewpoint in a variety of seemingly disparate projects. He has also completed a simulation study of the financial reserves of union health and welfare funds, and has turned to building a stochastic model of the oil and gas discovery process on a geological basis with a view to structuring optimal exploration strategies. Professor Shapiro's research during the past year has been concentrated almost entirely in the important area of integer programming in three aspects: theory, computation, and applications. Professor Gorry is associated with this project. Further theoretical progress has been made through development of an adaptive group theoretic algorithm. A wide class of applications is possible in the general area of combinatorial optimization, for example, non-linear integer programming, scheduling, and pattern recognition. Professor White's research has been concentrated during the past year in university systems analysis, and is reported below under the review of research on the management of education.

#### MANAGEMENT OF EDUCATION

A major interdisciplinary research effort got under way during the past year on the management of education, funded by two three-year grants from the Carnegie Commission on Higher Education and the Ford Foundation. Professor Schein, with the assistance of Professor Kolb, is examining the form and timing of higher education, extending work he

has already started in graduate management education to the education of architects, engineers, and other professionals. Professors Zannetos and Scott Morton are examining the impact of technology (particularly computer-aided instruction) on the structure of education and the careers of professors. Included in this is a review of the experience of the new "learning corporations." They are also working on an associative learning project, allowing the student to switch from programmed instruction to ask questions of the program, and to permit relationships between terms or concepts to be developed. Professor Amstutz is extending the computer-based system developed in the School to evaluate progress toward Course objectives as set by professors and students, to a more generalized model which can be tested in other types of higher education at colleges and universities in the Boston area. Finally, under separate support from the Ford Foundation to M.I.T., Professor White's research has focused on the problem of the management of university resources, which include personnel, physical space, equipment, and money. Whenever possible, the research is at the policy level, and covers items such as the setting of tuition fees, student aid funds, admissions, endowment management, and the budgeting process itself. Operations research systems and analysis are being used. The entire research program is coordinated by a committee consisting of Professors C. A. Myers, Schein, Zannetos, and Scott Morton.

#### MANAGEMENT OF PUBLIC AFFAIRS

There are a number of research projects in this important area, with coordination provided by Professor Haire. He has been active in the Urban Systems Laboratory and in bringing together at Woods Hole last summer M.I.T.-wide resources directed toward urban affairs research. Some of the research in this area has been reviewed earlier, including the effort, by Professors Kuh and Thurow, to build models of the housing industry which will estimate the impact of changes in the housing industry on the economy. Professor John F. Collins has been associated with the broader project on housing for the Urban Coalition, and he has also aided Professor Forrester in his research on urban dynamics. The research of the staff of the Industrial Relations Section on the manpower aspects of urban affairs has already been mentioned. Dr. Gordon F. Bloom, associated with the marketing group, has been developing case histories of business involvement in various forms of social investment, including plants in ghetto areas. He has also done research on the cost-disadvantage of retailing businesses in the ghetto. Stanley M. Jacks has organized a major interdisciplinary inquiry into the utilization of the islands of Boston Harbor, including the development of a new community in harbor space.

The research encompasses a description of the resource, constraints on its use, analysis of various possible alternative uses, and the development strategies associated with each alternative.

#### MANAGEMENT OF MEDICAL SERVICES

Professors Rockart and Gorry have taken the leadership in research in this field. Professor Rockart has studied the methods used by hospitals to schedule outpatients with a view to using computer techniques to improve scheduling of patients to specific doctors. The techniques have already been introduced in a multispecialist clinic, to provide a more efficient flow of patients through the clinic. Symptom questionnaires have been sent to patients prior to their visits to determine which doctors they should see, and the reaction of doctors to this system is being assessed. Professor Gorry has pursued his research in computer-aided diagnosis, particularly in the diagnosis of acute renal failure. Preliminary studies suggest that the data base, which includes subjective assessments, permits the program to perform at a very high level. Research is also continuing into the use of teaching programs centered around the basic diagnostic programs.

#### INTERNATIONAL PROGRAMS

The School continues to sustain its international perspective, but what was noted in last year's report in this connection continues to be an even more valid characterization of our efforts in this domain. I noted last year that earlier School emphasis in the international area had been on institution building, but that more recent efforts had moved in the direction of informal collaboration, research programs, and curriculum development. The School's new connection established this year with the government of Puerto Rico continues to emphasize this informal collaboration and research and we envisage almost no "institution building" activities in which our faculty will be directly involved. The earlier section on research at the School has once again preempted some of the *éclat* of this section, since many of the interests and the work of individual faculty members in the international area have been reflected in that preceding review. In this section I note some of the highlights of our international concerns and commitments which have not been noted earlier in this report.

#### INDIAN INSTITUTE OF MANAGEMENT, CALCUTTA

June 30, 1969, marked the planned termination of eight years of formal affiliation with the Indian Institute of Management, Calcutta. This has been a constructive association, and it is anticipated that strong in-

formal ties reinforced by continuing collaborative research will persist indefinitely.

Professor Warren Haynes of the Harvard Graduate School of Business Administration and Professor Hill of this faculty, assisted by Professor Howard Baumgartel of the University of Kansas and in collaboration with the Shri Ram Centre for Industrial Relations, New Delhi, have been engaged in a study of institution building focusing on the Calcutta Institute and two other management education institutions in India. Their findings, which will be published during the coming year, are expected to throw further light on the processes of technological transfer between nations.

#### LONDON GRADUATE SCHOOL OF BUSINESS STUDIES

The Sloan School advanced its cooperation with the London Graduate School of Business Studies to a higher level of participation of our faculty than previously. This year Professors Crowston and MacAvoy went to London to teach in the London School's version of the Sloan Fellows Program. Both of these faculty members taught half-term versions of subjects given here in the Sloan School: Professor Crowston offered the fundamentals of programming and Professor MacAvoy taught applied economic analysis of the behavior of large-scale firms engaged in American and foreign operations. In addition, the London Sloan students carried out a benefit-cost analysis of the British reactor program under Professor MacAvoy's direction. The paper resulting from this study will be published in a London journal this fall.

The relationship between the Sloan School and the London Graduate School of Business Studies continues to be close in other ways. Sloan faculty members have continued to consult with planning groups from London interested in developing new programs; in particular, there has been close contact with those London faculty members responsible for developing a new Ph.D. program scheduled to start in the coming academic year. A number of visits have been made by London School faculty members to Boston in the last year and several Sloan School faculty have visited London to consult on these developments.

#### M.I.T. FELLOWS IN AFRICA AND COLOMBIA STUDIES

Last year's report summarized the basic character and purpose of the M.I.T. Fellows in Africa and Colombia Programs which were officially concluded last year. I also described there the analysis of these programs which has been undertaken by Professor Rubin, by James Stoner (formerly at M.I.T. and now at Columbia University), and by John

Aram (also a former member of the School who has now moved on to Case Western Reserve University). At present, a draft of the entire manuscript is completed and I anticipate the availability of a manuscript for wider circulation by the end of the summer. The published study should provide a careful review of what has been a fascinating set of programs.

#### BRAZILIAN DEVELOPMENT BANKING PROJECT

Transfer of basic management technology in a developing country is the purpose of the Sloan School's cooperative effort with Brazil's National Bank for Economic Development (B.N.D.E.). Packages of "management tools" are designed for acceptance by Brazilian institutions which: (1) can use them themselves, and (2) have some leverage to influence their use in medium or small industries in Brazil.

It is hoped that such a strategy will improve the human and institutional resources of Brazil's 20-bank development finance system and the more than four hundred projects to which the system has lent more than \$100 million equivalent in medium and long-term loans. The project is supported by a Ford Foundation grant.

There are four operational goals: (1) the design and implementation of management information and control systems to provide necessary data for control and decision making by the private industrial borrower, the agent banks, and the FIPEME Nucleo (B.N.D.E. special loan fund nucleus); (2) the design and implementation of an organizational development program to complement the information systems by creating effective management practices and working relationships among the people and institutions using the data; (3) the elaboration and propagation of the concept of an effective, interacting national system of development finance institutions; and (4) the elaboration and propagation of the concept of the professional specialist in development finance.

The project is currently assisting B.N.D.E. in the second basic course for Brazilian development bankers, which is designed to improve their managerial, appraisal, and control capabilities. An information and control system manual, new case material, a textbook, and a development banking game are among the materials the project has under development. A total of 18 project working papers have been completed at the School and a number of the concepts in the papers are currently being implemented by B.N.D.E. A research project designed to provide a better understanding of the process of this type of technical assistance is also under way.

The project is directed by Professor Nyhart. Professors Farris, Rockart, Hill, and P. E. Roberts have also been active on the project. In addition, five Sloan School students are working on the project as research assistants.

SLOAN SCHOOL PUERTO RICO PROJECT

When Luis A. Ferré, an alumnus of M.I.T. and a member of the Corporation, was elected Governor of Puerto Rico, conversations were begun between the Sloan School and the Commonwealth of Puerto Rico to explore the ways in which resources in the field of management could be made available to the Governor. Dr. Chandler H. Stevens was appointed to the staff of the School and sent, on leave, to be a member of Governor Ferré's staff and to take part in the formation of an advisory commission on governmental developmental problems. Dr. Stevens serves as a liaison with M.I.T. and with the mainland resources in general. A variety of projects have been initiated by the commission, and the School has been instrumental in providing both impetus and expert support for some of these projects. Work is proceeding on an analysis of the compensations schedules for government employees, on problems of transportation, on the development of social indicators for policy decision makers, on both the description and an analysis of the tax base and the attendant possibilities of tax reform, and on possible government reorganization. Dr. Stevens will stay in Puerto Rico until February, 1970, at which time it is anticipated that a viable link will have been developed.

VISITING INTERNATIONAL FELLOWS

Our visitors from other countries this year included Dr. John Russell King of the Imperial College of Science and Technology, London, and Keith John Blois, also from England, where he was Lecturer at the Loughborough University of Technology. These guests were with us for the academic year.

Dr. Janusz W. Goscinski, Assistant Professor at the University of Lodz and Deputy Director of the Polish Management Development Center at Warsaw, Poland, was a guest at the Sloan School for the spring term.

STAFF PROMOTIONS AND CHANGES

I am pleased to announce the promotion of Gordon M. Kaufman and Paul W. MacAvoy to the rank of Professor and the promotion to the rank of Associate Professor of Thomas J. Allen, Wallace B. S. Crowston, David B. Montgomery, Michael S. Scott Morton, Stewart C. Myers, and Jeremy F. Shapiro. Tenure was granted to Associate Professor Edward B. Roberts. Promoted to Assistant Professor were Thomas P. Gerrity Jr. and Dennis L. Meadows.

We are especially pleased to report that Dr. Edward H. Bowman has returned, as Professor of Management, to the Sloan School at M.I.T. after a period of time at Yale University where he served as Comptroller.

Two members of our faculty retired at the end of the academic year.

They are: Professor Douglass V. Brown, Alfred P. Sloan Professor of Industrial Management, and Billy E. Goetz, Professor of Management. Professor Brown will continue working with us on a part-time basis in his emeritus status.

I am pleased to record that Professor J. Daniel Nyhart will assume the post of Dean for Student Affairs at M.I.T. this coming September. Professor John D. C. Little has agreed to assume the responsibility of Director of the Operations Research Center at M.I.T. while maintaining his professorial rank and duties at the Sloan School.

Joining us this fall in the Assistant Professor rank will be James E. Annable Jr., who comes to us from Princeton University to be associated with the industrial relations group; John Heñize, who joins our industrial dynamics group and who comes to us from the M.I.T. Instrumentation Laboratory; Paul R. Kleindorfer, who comes from Carnegie-Mellon University and will be associated with the operations management group; and Roy E. Welsch, who will join the quantitative methods group and is coming here from Stanford University.

Professor Donald C. Carroll was on sabbatical leave this past year to enable him to complete work on his forthcoming book. Professor John D. C. Little also was on sabbatical leave to devote full time to his research work on adaptive control systems for managerial processes. Professor Zenon Zannetos was on his sabbatical leave last year to devote full time to his major research projects. Professor Sidney S. Alexander returns from his leave of absence with the RAND Corporation. Professor David Taylor has been on leave for the spring term and will be on leave next year to enable him to act as Executive Assistant to Dr. George Shultz, the Secretary of Labor. Professor Thomas Allen was on leave from here for the spring term to be a Visiting Senior Lecturer at Manchester Business School, University of Manchester, United Kingdom; and Professor Glen Urban was on leave for a three-month period to the Indian Institute of Management, Calcutta.

We were fortunate to have with us as Research Associate for the spring term, Dr. Erich Jantsch of Austria, as a visitor from the Directorate for Scientific Affairs of O.E.C.D. (Organization for Economic Cooperation and Development) in Paris. Dr. Jantsch conducted a series of lectures and a seminar in the management sciences. Dr. William Kennedy joined us last September, also as a Research Associate, to assist Professor Zannetos in his portion of the School's research project on the management of education. Professor Donald White of Boston College will continue as part-time Visiting Professor this coming year with the industrial relations group of the Sloan School. M. Scott Myers will be with us this coming year as a Visiting Professor in the organizational behavior area. Dr.

Myers has been a management research consultant for Texas Instruments Incorporated for several years. Joining the same group as Visiting Lecturer will be Mrs. Dorothy E. Wedderburn of the Imperial College, University of London, where she is Lecturer in Industrial Sociology.

Dr. Chandler H. Stevens joined the Sloan School this year as a Senior Lecturer. He will be on leave the fall term of 1969 to complete an assignment in Puerto Rico where he is assisting and acting as a liaison man for the Governor, Luis Ferré.

New instructors joining us this fall will include Russell B. Faucett, Dario Iacuell, Murat Sertel, Joel Shwimer, and Jarrod W. Wilcox.

I must record as resignations this year that of Dr. Miles Kennedy, who will now become an Associate Professor at the School of Management, Case Western Reserve University; and Dr. John Pierce, who will assume new duties as a consultant to industry. Dr. Kenan E. Sahin will join Robert College in Turkey. These men have contributed greatly to the Sloan School in the past few years and we wish them well in their future endeavors. Dr. Michael J. Brower resigned his post as Assistant Professor but he will continue with us in a visiting capacity for one year to complete his research work on South American business economics. Leon Liebman, who was with us one year as an Instructor, has accepted a position at the Wharton School of Finance and Commerce at the University of Pennsylvania.

#### STAFF ACTIVITIES AND AWARDS

The professional activities in teaching, research, and a variety of action and consulting programs in which our staff has been engaged were once again legion in number. The distinctions this work has brought to the individuals is only partially reflected in this listing of staff activities and awards. The pride I take in recording these distinctions is one which extends both to the men concerned and to the reflected distinction garnered for the School as a consequence of these activities.

During the year Professor Alexander was on leave to the RAND Corporation, where he continued his work on a study of the economic and political problems of the Middle East.

Professor Allen was on leave for the spring term at the Manchester Business School and extended his research program on communication within and among R & D laboratories into the area of international technology transfer — an extension made possible by the renewal of an NSF research grant.

Professor Amstutz served as a member of the Cambridge Project and in this connection worked with other M.I.T. and Harvard faculty members to develop an organization structure and program for the joint Har-



vard-M.I.T. program on the application of computer technology to the social sciences. During the academic year he presented papers in meetings of the Institute of Management Science, American Marketing Association, the Operations Research Society of America, the Association for Computing Machinery, and the Canadian Operations Research Society. In addition, he lectured at several American universities and with Professors Haire, Zannetos, and Carroll presented a one-week seminar for French managers in Versailles, and with Professor Silk, a one-week course in France focusing on the applications of systems analysis to international marketing problems.

Richard Beckhard continued to serve as chairman of the Executive Committee of the National Training Laboratories Institute for Applied Behavioral Science. During the year he delivered invited papers at the Industrial Relations Research Association, the Danish Association for Commercial and Industrial Education, and the Operacion Desarrollo in Bogota, Colombia.

Dr. Bloom served as a member of the Executive Committee and Board of Directors of the National Association of Food Chains and was a member of the Emergency Economic Stabilization Food Retailing Industry Committee.

Professor Brower spent the summer at the Universidad del Valle in Cali, Colombia, where he offered a course in the Advanced Management Program; he also taught in Bogota during this period. He served on the Northwestern University/Ford Foundation Visiting Committee to the new Institute for Advanced Management Studies in Caracas, Venezuela. During the year he delivered a series of invited talks at the Maxwell School, Syracuse University, on investment in human resources as part of a national development program.

In January, 1969, Professor Brown was named president-elect of the Industrial Relations Research Association for the year 1970. He continues to serve on the Advisory Committee of the School of Business of Atlanta University and has served this year as Chairman of the Examining Committee of the Graduate School of Business, University of Chicago. During the year Professor Brown was named Chairman of Mayor Kevin White's commission to study the structure of the City of Boston for handling personnel and labor relations.

Professor Collins continues to serve as a member of many prominent national committees, including the American Bar Association Special Committee on Housing and Urban Development Law; the Special Committee of the National League of Cities; the Technical Advisory Board Panel on Local and State Government Response to Technological Opportunities and Problems of the U.S. Department of Commerce; the National

Advisory Council on Vocational Rehabilitation of the Department of Health, Education and Welfare; the Task Force on Housing, Reconstruction and Investment; and the Steering Committee of the National Urban Coalition. Professor Collins during the year also delivered a number of invited and main lectures dealing with a broad variety of problems in the management of cities.

Professor Cootner continued to serve as associate editor of the *Journal of Finance* and addressed a conference of the New York Society of Financial Analysts, Computer Applications Committee.

Professor Crowston was elected secretary-treasurer, Boston Chapter, T.I.M.S. (The Institute for Management Sciences) for 1969-70. He also gave 15 lectures to the Sloan Fellowship Program at the London Graduate School of Business Studies.

In July Professor Durand returned from Berlin, where he had spent six months under the auspices of the exchange program between M.I.T. and the Technical University of Berlin.

Professor Farris delivered a number of invited lectures for several societies and workshops, including the International Congress of Applied Psychology in Amsterdam; the American Psychological Association; the Council for Latin America Workshop in Chicago; and the Cornell University Workshop on International Studies of Organizations.

Professor Forrester received the Inventor of the Year Award from the Patent, Trademark, and Copyright Research Institute of the George Washington University for his earlier work on magnetic core computer memory. He also delivered a number of invited papers on his most recent principal research efforts in urban dynamics.

Professor Galbraith became vice chairman of the College on Organization in The Institute for Management Sciences and chairman of the Operations Analysis Committee of The Academy of Management.

Professor Goetz has served on the Board of Directors of University Affiliates. He was made a Life Member of the Society for the Advancement of Management.

Mr. Goodwin continued as a national governor for the Boston Chapter of the Society for the Advancement of Management and as a trustee of the International Work Simplification Institute. He also served as director of the Executive Conference on Managing Improvement conducted annually for industry on Cape Cod and remained active as a member of the board of directors or executive advisory board of several companies.

Professor Gorry delivered a number of invited papers on computer-aided diagnosis and models of decision processes in health services.

Professor Holland served as editor of the *National Tax Journal* and was a member of the Executive Committee, the Committee on Commit-

tees, and the Committee on Education of the National Tax Association; he was also a member of the Committee on Taxation, Resources, and Economic Development. Professor Holland received the 1968 Elizur Wright award from The American Risk and Insurance Association, "In recognition of his outstanding original contribution to the literature of insurance," for the book, *Private Pension Funds: Projected Growth*.

Mr. Jacks has remained active in an interdepartmental team on the Boston Harbor islands project, a team established under contract with a Special Commission of the Massachusetts Legislature. He also remains active as an arbitrator of labor-management disputes.

Dr. Erich Jantsch was co-editor of the international journal, *Technological Forecasting*, and served as participant or consultant to a number of foreign governments and international organizations on issues involving scientific and technological strategies.

Professor Jones was elected to serve on the Board of Directors of the Computer Programming Center of Boston and is a member of the Board of Directors of The Rivers Country Day School in Weston.

Professor Kaufman served as a referee for *Econometrica* and the *Journal of the American Statistical Association* and as a director of American Store Equipment Corporation and Geriatric Services Incorporated. He also served on a board of ten academic consultants set up by the Army Materiel Command (AMC) to examine the quality and style of its internal research on the applications of management science and applied math to AMC problems.

Professor Kindleberger continued as a trustee of Clark College in Atlanta, Georgia, was chairman of the A.E.A.-E.T.S. (American Economic Association-Educational Testing Service) Committee on the Graduate Record Examination in Economics, and was a member of the Program Committee of the International Economic Association for its meeting held in September. Throughout the year he continued to present, as he has in past years, a large number of invited papers and talks to a variety of professional associations and educational organizations.

Professor Kolb continued as consultant with the Peace Corps and A.I.D. (Agency for International Development) on staff training and cross-cultural training.

Professor Kuh continued as a member of the Executive Committee of the Brookings-S.S.R.C. (Social Science Research Council) Econometric Model Project and as a member of the Institutional Computer Facilities Section of the Office of Computing Activities, NSF. Professor Kuh has also been an advisor to Governor Ferré's Advisory Council on New Governmental Programs in Puerto Rico.

Professor Little served as associate editor of *Management Science*:

*Applications.* He and Leonard Lodish received the Annual Media Award (for an advance in media research methods) sponsored by *Mediascope* magazine.

Professor MacAvoy continues to serve as a member of the Board of Economic Advisors to the Secretary of Transportation and of the Council of Economic Advisors of the State of New York. He also gave several lectures at the London Graduate School of Business Studies during the fall term.

Professor Marquis was President of the New England Psychological Association. He was also a member of the Council and the Committee on Facilities and Development, American Academy of Arts and Sciences; a member of the U.S. National Commission for UNESCO; (United Nations Educational, Scientific and Cultural Organization); and a member of the Committee on International Relations, American Psychological Association.

Professor Martin was a reviewer for *Computing Reviews* and delivered a paper to the Annual Systems Science Conference in Hawaii.

Professor Mills has been appointed as an advisor to the Office of Policy Planning of the U.S. Department of Labor regarding industrial relations in construction, and served throughout the year as consultant to a number of other governmental agencies, including the Model Cities Administration of the Department of Housing and Urban Development and the Building Research Advisory Board of the National Academy of Sciences.

Professor Modigliani was a member of the Executive Committee and the Committee on Publications of A.E.A.; he was also a member of the Board of Directors, the Committee on Economic Stabilization, and the Subcommittee on Monetary Research of S.S.R.C.

Professor Montgomery was selected departmental editor: marketing for *Management Science: Theory* and *Management Science: Applications*. He served as sub-editor for computer applications, *Journal of Marketing Research*, and served on the National Program Committee, A.M.A. Educators' Conference, held in Denver in August.

Professor Leo B. Moore served as chairman of the Research and Education Committee, Standards Engineering Society, and as Vice President of Research, International Work Simplification Institute. He was a member of the following: Board of Directors, Society for Advancement of Management, Boston; Advisory Committee, *Journal of Creative Behavior*; Editorial Board, *Standards Engineering Magazine*; Creative Leadership Council, Creative Education Foundation, University of New York at Buffalo.

Dr. Richard S. Morse continues to serve in a large variety of management consulting, directorship, board membership, and government stud-

ies membership capacities. He served, for example, as a member of the Advisory Board of the Air Force Systems Command, as trustee of the Midwest Research Institute, as a director of the New England Council, as a trustee of the Research Analysis Corporation, and as director of the Japan Fund.

Professor C. A. Myers was one of the recipients of the Pennsylvania State University, College of Business Administration, 1969 Alumni Achievement Awards. In January Professor Myers was elected Chairman of the National Manpower Policy Task Force, which is funded by the Manpower Administration of the U.S. Department of Labor. In June he was invited to lecture at the Salzburg Seminar in American Studies in Austria.

Professor S. C. Myers continues active in a number of outside conferences and seminars and as consultant to the Office of Economics, Federal Power Commission.

Professor Ness delivered a number of invited lectures at the Naval War College, a series of lectures in Paris and in London on management information systems and continued to serve as an officer of Advanced Information Applications, Inc.

Professor Nyhart continued to serve as a consultant on development banking to O.E.C.D.'s Development Centre and as project co-ordinator of the M.I.T./B.N.D.E. Development Bank Training and Research Project and consultant to B.N.D.E. He also served as a consultant to the Bureau of the Budget and to the Office of Economic Opportunity.

Professor Pierce was a member of the Operations Research Committee of the Technical Association of the Pulp and Paper Industry.

Professor Pogue continues as consultant for the Institutional Investor Study of the Securities and Exchange Commission.

Professor Roberts continued as a member of the National Council of T.I.M.S. He was reappointed to the Air Force Scientific Advisory Board and to the Department of Commerce Technical Advisory Board. Professor Roberts also received an appointment as the James V. Forrestal Chair of Military Management occupant at the Naval War College.

Dr. Robinson was elected president of the Association for Education in International Business; governor, member of the Executive Committee, and chairman of the Finance Committee, Institute of Current World Affairs; and a member of the Board of Directors of the American Research Institute in Turkey. He served on the Editorial Review Boards of *The Journal of Developing Areas* and the *Academy of Management Journal*.

Professor Rockart served as a referee for the Business Applications section of *Communications of the A.C.M.* and continued his consulting

and research efforts in health services at the Lahey Clinic and the Massachusetts General Hospital.

Professor Rubin's leadership in the behavioral science research practicum and the research methods subject that preceded it was a key factor in his being awarded one of the Everett Moore Baker Awards for outstanding undergraduate teaching. This award is student-initiated and implemented.

Professor Schein was a member of the Committee on Basic Research in Education, National Research Council, and a member of the Board of the North American Research Organization on Management.

Professor Shapiro served as a referee for *Operations Research*, *Management Science*, and *SIAM Journal on Applied Mathematics*.

Professor Siegel was appointed to the Panel of the New England Plan of the American Arbitration Association, a fact-finding and mediation panel for dispute settlement in the public sector, and was invited to become a member of the National Committee for Support of the Public Schools. He served as chairman of a panel on union-management cooperation at the Industrial Relations Research Association meetings. He continues his membership in a number of professional committees, including the Advisory Committee of the New England Board of Higher Education; the Policy Committee, A.T.G.S.B.; the Interstate Conference on Labor Statistics of the Bureau of Labor Statistics, U.S. Department of Labor. He remains active as an arbitrator and fact-finder in dispute settlement and serves as an elected member of the Framingham School Committee and of the South Middlesex Regional District Vocational and Technical High School Committee.

Professor Silk served as a referee for the *Journal of Business*, *Management Science*, Series B, and *Industrial Management Review*.

Professor Thurow served as consultant for the Bureau of the Budget, Department of Health, Education and Welfare, and the Council of Economic Advisors. He served also in a consulting capacity for the RAND Corporation and Data Resources.

Professor Urban was on leave during the spring term at the Indian Institute of Management, Calcutta. He was a referee for *Management Science: Applications*.

Professor White served as associate editor of *The Bulletin* of T.I.M.S., member of the Education Committee of O.R.S.A. (Operations Research Society of America), and chairman of the M.I.T. chapter of A.A.U.P. (American Association of University Professors). He was assistant to the Vice President for Organization Systems at M.I.T. from September to March and was special consultant to the Governor of Massachusetts from March through June.

Professor Carroll L. Wilson continued as consultant with the United Nations, the O.E.C.D., the Council on Foreign Relations, the National Academy of Sciences, and the American Academy of Arts and Sciences. He served also with the Woods Hole Oceanographic Institution and as consultant to a number of private companies.

Professor Zannetos continued as a Vice President and Director of Research of the College of Measurements of Management of the Institute of Management Sciences. He served as a member of the American Accounting Association Awards Committee.

#### STUDENT ACTIVITIES AND AWARDS

The Graduate Management Society is our graduate student organization. During this year the organization has broadened its traditional areas of activity. The organization's members have worked to strengthen student ties with their contemporaries at the Harvard Business School (H.B.S.). Included in this program have been joint H.B.S.-Sloan lectures followed by a social hour, and an effort to increase the flow of student information between the schools so that students may take advantage of the cross-registration policies more wisely. Also, next fall the organization plans to publish and distribute a resume book consisting of one-page individual resumes of the Class of '70. The athletic, speakers, and social programs have been as strong as in the past, with the notable exception that the organization replaced the traditional school-sponsored dinner for graduating students with an end-of-year Sloan party to which all faculty members and graduate students were invited. The President of the organization elected for the fall term was Pamela W. Turner, and for the spring term, Robert C. Todd.

The *Industrial Management Review (I.M.R.)* is now in its tenth year of publication, and continues to grow. Last year the editors devoted considerable thought and effort to defining the role of the (*I.M.R.*) more carefully, with particular emphasis on the somewhat competitive goals of publishing the most advanced scholarly research and diffusing that research to the professional manager in a form in which he can implement it. The editors have sought to aim the *Review* at the technically trained professional manager seeking to maintain his skills in a profession undergoing continuing rapid change. Editorship of the *Industrial Management Review* is awarded to outstanding graduate students in the Sloan School. For Volume 10, the student editors were: Peter R. Brody, David L. Diamond, Lawrence W. Garrett, Robert L. Gipson, James M. Piepmeier, and Anthony C. Taylor. For Volume 11, the *I.M.R.* editors are: Richard O. Bond, Stephen D. Jones, Paul T. Pureka, and James B. Smith III.

The Sloan Traders is an investment club organized by the students in

1967 to provide real-world experience in portfolio management. The club manages a Capital Growth Fund, begun with a \$5,000 investment fund from M.I.T., which provides the students with practical experience in the problems and policy of real fund management. The fund had a market value of more than \$8,000 at the end of the 1968-69 academic year.

This year the club conducted an investment contest. Upon payment of an entry fee each student was allowed a hypothetical initial fund of \$10,000 to "invest" as he wished. The accumulated entry fees, nearly \$100, were the prize awarded to the participant who achieved the greatest capital gain with his "fund" during the year.

The club also sponsored a series of lectures on market theory and operation by academicians and leaders in the financial community.

I am pleased to note the following awards and honors achieved by students of the Class of 1969. The Brooks Prize for the best thesis submitted for the degree of Master of Science in Management was awarded this year to Dean R. Ericson. His thesis was entitled, "Urban Minority Business Development: The Problem of Resource Channeling through Intermediary Institutions."

We did not produce a winner in the State Farm Companies Foundation Exceptional Student Fellowship Awards (as we had in the past two years), but one of the winners, Joseph Richard Matson of Ohio State University, has been accepted for graduate work in Sloan School for September, 1969, admission. The Sloan School of Management Senior Award went to Michael Jay Ginzberg. At the annual awards convocation in May, 1969, Course xv students received the following: Joel M. Hemmelstein, a junior, won a Saliver Award in Athletic Administration; Cleveland Scudder Smith, a senior, won a Certificate Award in Athletic Administration; and another senior, Wendell Carl Brase, won a Baton Society Award for able administration of the M.I.T. Symphony Orchestra and the M.I.T. Combined Musical Clubs.

#### GRADUATE ALUMNI ASSOCIATION

Perhaps the most significant feature of the Graduate Alumni Association's progress during the year is its continued existence and the abounding enthusiasm for the organization. Clearly, the value of the Association to its constituents around the country is recognized. With this support has come the development of a national organization of graduate alumni of the Sloan School. Thus, the Graduate Alumni Association has consolidated its gains by infusing its local and regional groups with additional volunteers; by developing organized groups in Washington, D.C., Chicago, and Los Angeles; by establishing a national organization; and by planning ahead for a reunion in June, in conjunction with the M.I.T. Com-



mencement activities, for a second Boston meeting later in 1969, and for a national convocation to be held in 1970.

The second issue of the Graduate Alumni Bulletin came off the presses in February and was mailed to all graduate alumni of the Sloan School. In keeping with the objectives of the publication, this issue included articles reflecting developments at the School, academic concerns of the faculty, and a comprehensive list of suggested readings in the field of management.

Again this year, Sloan Fellows alumni work sessions were conducted in New York City, Washington, D.C., and London, when the current Sloan Fellows visited those cities on their management study field trips.

Finally, an alumni event of great interest, held every three years, the 1968 Sloan Convocation for alumni of the Alfred P. Sloan Fellows Program and the Program for Senior Executives, was held October 10-12, centering on the theme, "The Management of Social and Technological Change." Papers were presented by Professors Walter A. Rosenblith, Paul A. Samuelson, Charles A. Myers, John F. Collins, Robert C. Wood, and by Russell De Young (Sloan Fellow '40), Chairman, Goodyear Tire and Rubber Company. Working seminars were conducted also by members of the Sloan School faculty. More than 350 alumni and wives attended the three-day Convocation.

#### THE ADVISORY COUNCIL

Due to a combination of circumstances the Advisory Council did not meet during the past year. A meeting was scheduled for May 12 and many members of the Council made plans to attend. Materials were prepared and distributed to the members. But in late April I was asked by President Howard W. Johnson to serve as Chairman of a Panel to review M.I.T.'s relationships with its two large special laboratories. Dean Siegel worked as director of staff for the Panel.

Since the Panel's first report was due on May 31, it was necessary to cancel all other activities for the month of May and unfortunately these included the meeting of the Advisory Council. It was impossible to re-schedule the meeting during the short time remaining in the year.

I regret very much that the meeting could not be held for a variety of reasons, not the least of which was that I wanted very much to welcome William S. Brewster, Chairman of the Board, United Shoe Machinery Corporation; Hugh S. Ferguson, Retired President, National Research Corporation; and Roger P. Sonnabend, President and Chief Executive Officer, Hotel Corporation of America, who joined the Council this year as new members. I do want to take this opportunity to thank all the members for their service during the year just ended and to express my special

appreciation to James M. Barker, Director, Allstate Insurance Company; W. Gardner Barker, President, Thomas J. Lipton, Inc.; John L. Burns, Chairman of the Board, Cities Service Company; Elisha Gray II, Chairman of the Board, Whirlpool Corporation; William B. Murphy, President, Campbell Soup Company; Hoyt P. Steele, Vice President, General Electric Company; and William S. Wheeler, Vice President and General Manager, Sylvania Electronic Systems Eastern Division, whose terms on the Council expired during the year. I especially want to express the appreciation of all of us in the School to Elisha Gray, who served for the past three years as Chairman of the Council, for his most constructive suggestions and advice during his term of office. I'm looking forward to working with George R. Vila, Chairman and President, Uniroyal, Inc., who has agreed to serve as Chairman of the Council.

#### ADMINISTRATION OF THE SCHOOL

The accomplishments of the School over the past year were due to many people. Faculty members, students, secretaries and staff members all made important contributions. It would be inappropriate, however, not to mention the very great contributions of the School's administrative personnel. Dean Siegel's contribution included specific activities that ranged from student counseling to faculty planning to facilities design, but to attempt to list all the things he did would be neither possible nor serve any useful purpose. His contribution can be summarized best, perhaps, by saying that every person in the School could cite ways in which his positive and insightful approach to every situation has made the School a more effective and rewarding place to be. I know I speak for many people, including myself, in expressing appreciation for what he has done.

Perhaps the best way to judge the contribution Dean Gil has made to the School is to look at the programs for which he is chiefly responsible. The Sloan and Senior Executive Programs are, by any measure we can find to apply, the best programs of their kind. Their particular quality is that they yield substantial benefits to all those who participate in them, faculty and staff, as well as the participants themselves. This important characteristic of these programs is due in large measure to Dean Gil's effective and imaginative management of them.

Beyond the regular Executive Programs, Dean Gil also organized and ran a new program aimed at serving the interest of urban executives. This program was offered twice during the past year and its success was due to a very considerable extent to the efforts of Dean Gil and his staff.

But during the past year Dean Gil's activities extended considerably beyond the already broad domain of the Executive Programs. He served on the School's Policy Committee, taught a subject that included graduate

students as well as Sloan Fellows, and organized a research project which he will undertake during the coming year. I am pleased to have this opportunity to say how much all of us appreciate Dean Gil's particularly effective contribution to the School.

The School was not administered by deans alone, however. Their efforts were guided and supported by a number of able and hardworking people. Gertrude E. Burns continued to manage the School's financial resources with skill, imagination, and good humor. She is the person to whom people invariably turn for answers to hard questions, particularly where money is concerned. Polly Karb, who successfully completed her Master's degree in Educational Administration at Northeastern University during the past year, continued to carry the principal administrative responsibility for our executive programs under Dean Gil. Miriam Sherburne worked closely with Professor Hill and Dean Siegel in managing our graduate programs, from recruiting through alumni relations. Esther Merrill was responsible not only for many aspects of our undergraduate program but also for class scheduling, space and office assignments, and secretarial personnel — an extremely demanding set of responsibilities which she handled with great skill.

This description of the administrative organization would be seriously incomplete if I did not note the special contribution made by Margaret O'Brien, who served as my secretary. Her great skill and patience as well as ability to think and work far beyond the boundaries of her normal duties made my efforts far more effective than they would otherwise have been.

I know Deans Siegel and Gil would also want me to indicate their appreciation for great contributions which their secretaries Grace Locke, Jan Jefferson, and Sandra Anthony made to their efforts and to the School.

WILLIAM F. POUNDS



## SCHOOL OF SCIENCE

Looking back over the period of a year, it is possible to see in better perspective some of the changes that are taking place day by day in the instructional and research programs of the School of Science. In instruction the year has been marked by the introduction of a greater variety of freshman programs, the planning of new types of freshman programs for 1969-1970, the evolution of departmental upperclass and graduate programs, and the completion of the first year of the Joint Graduate Program in Oceanography with the Woods Hole Oceanographic Institution.

There were two new options for satisfying the physics requirement this year, 8.011 and 8.021, taught by Professor Robert I. Hulsizer Jr., and 8.01S, taught by Professors Daniel Kleppner and Robert J. Kolenkow. The regular 8.01 was taught by Professor Eric R. Cosman in the fall and Professor Harald A. Enge in the spring. The regular 8.02 was taught by Dr. Harry M. Schey in the fall and Professors Hale V. Bradt and George Bekefi in the spring. In the Department of Mathematics, Professors Alar Toomre and Steven A. Orszag taught 18.01 in the fall. Professor Gian-Carlo Rota taught 18.02 in the fall, and Professors Toomre and Daniel J. Kleitman taught it in the spring. Professor James R. Munkres taught 18.01S. This was the first year that there were alternates to Chemistry 5.01. Organic Chemistry, 5.41, was taught by Professor Daniel S. Kemp. Chemical Thermodynamics, 5.60, was taught by Professor Carl W. Garland in the fall and by Professor Glen E. Gordon in the spring. In the fall 5.01 was taught by Professors Isadore Amdur, Lawrence J. Heidt, Richard C. Lord, and Clark C. Stephenson, and in the spring it was taught by Professors Heidt, Charles D. Coryell, and James L. Kinsey. The Department of Metallurgy and Materials Science offered 3.091.

During the year new academic programs for 1969-1970 have been developed for freshmen. The following three small-scale experimental programs will be available in September, 1969:

1. Seminar-Tutorial Option (STO), which replaces the usual lecture-recitation section pattern with a seminar-tutorial pattern,
2. Unified Science Study Program (USSP), in which the emphasis is on learning through work on open-ended projects, and
3. Experimental Study Group (ESG), in which students and faculty collaboratively work out the content, pace, and style of learning for the strongly motivated student.

The first of these options has been developed by Professor Earle L. Lomon of the Department of Physics and Professor Rota of the Department of Mathematics, the second by Professor Jerrold R. Zacharias of the Department of Physics and Dr. Judah L. Schwartz and the staff of the Education Research Center, and the third by Professor George E. Valley Jr. of the Department of Physics and his colleagues. These developments are all pointed in the direction of giving more individualized instruction and providing the best possible environment for learning.

The number of undergraduate majors in the School of Science was essentially the same in October, 1968, (927) as in October, 1967 (929). There was a drop in the number of regular graduate students during this period (from 1,031 down to 1,014). In view of the threatening situation with respect to Selective Service, this is a very small decrease. The number of postdoctoral appointments also showed essentially no change from the previous year; there were 90 in biology, 77 in chemistry, 11 in earth and planetary sciences, 5 in mathematics, 5 in meteorology, 10 in nutrition and food science, and 72 in physics.

The Camille Dreyfus Building for the Department of Chemistry is approaching completion and should be available for use in the fall of 1969-1970. In January it was announced that Professors George H. Büchi, F. Albert Cotton, and John C. Sheehan have been named Dreyfus Professors of Chemistry for the academic years 1969-1971, in recognition of their outstanding contributions to chemistry.

Excellent progress has been made in constructing the 400-MeV electron accelerator (LINAC) at Middleton, under the responsibility of Professor Peter T. Demos of the Laboratory for Nuclear Science. The approximately 600-foot underground vault and the instrument and office buildings have been completed. It is hoped that the installation of equipment may proceed rapidly enough to provide a 500-MeV beam by the fall of 1970.

The apprehension about Federal funding, referred to in last year's annual report, has continued. In September faculty members were notified

that in fiscal year 1969 they would have to live on about 80 per cent of the National Science Foundation (NSF) funds they had previously been told were granted. Since some of the funds already had been spent during the summer, a larger cut was required in the remaining expenditures for the year. However, some economies could be effected; the Institute was able to supply some funds; and some relief was later obtained from NSF; thus it was possible to complete the year without serious damage to NSF-sponsored research programs.

During the year plans were completed for the development of a local optical observatory with a 24-inch reflecting telescope for instruction, research, and the testing of new astronomical equipment. Outside funding is now being sought. This facility is needed to supplement our strong programs in radio, radar, and X-ray astronomy.

The name of the Department of Geology and Geophysics was changed to the Department of Earth and Planetary Sciences. This indicates increasing interest in the various objects in the solar system and their relationships. Professors Klaus Biemann, Patrick M. Hurley, and Frank Press, and Dr. William F. Simmons are scheduled to receive samples of rocks from the moon this summer. This year the Department of Earth and Planetary Sciences has supervised a new program (XII-B) in the physical sciences, leading to the degree of Bachelor of Science without designation of field. This curriculum, which is arranged individually in consultation with an advisor to meet the specific needs of the student, has been quite successful.

This year the number of retiring professors was considerably larger than usual: Cecil G. Dunn and Robert S. Harris (Nutrition and Food Science), Lawrence J. Heidt (Chemistry), Kurt S. Lion (Biology), Philip M. Morse (Physics), and Francis O. Schmitt (Institute Professor). This group has made many important contributions to the life of the Institute.

During the year several new appointments of tenured faculty have been made from outside the Institute. These include Associate Professor Jack E. Baldwin (Chemistry), Professor Michel Baranger (Physics), Dr. Willem V. R. Malkus (Mathematics), Professor Arnold L. Demain (Nutrition and Food Science), and Professor Kenneth G. McCracken (Physics).

Members of the School of Science received many honors during the year; it is not possible to list them here, but I am happy to report that Professors Herman Feshbach and Benjamin Lax of the Department of Physics, and Professor Boris Magasanik of the Department of Biology became members of the National Academy of Sciences. Professor Francis E. Low was named the Karl Compton Professor of Physics. On January 23, 1969, Professor Isadore M. Singer of the Department of Mathematics

was awarded the Bocher Memorial Prize by the American Mathematical Society at its 75th annual meeting, which was held in New Orleans. The Bocher Prize, awarded once every five years, is the oldest award of the Mathematical Society. Previous winners from the Mathematics faculty were the late Norbert Wiener (1933) and Norman Levinson (1953).

ROBERT A. ALBERTY

### DEPARTMENT OF BIOLOGY

During the year 140 undergraduate students concentrated in the life sciences and 39 were awarded the S.B. degree in this field; of those, 8 submitted a thesis. There were 100 graduate students, almost all candidates for the Ph.D. degree. Between July 1, 1968, and June 30, 1969, 22 Ph.D. degrees and 3 S.M. degrees were awarded in Biology.

### CURRICULUM

Under the old system the students were required to take a chemistry laboratory, 5.31, an introductory biology laboratory, 7.02, consisting of projects in two biological areas, and laboratory subjects in biochemistry, genetics-microbiology and cell biology. All laboratories were 12-unit subjects, and as such were meant to require two afternoons of work per week. We learned by experience that it is not possible in such relatively short time both to teach methodology and to permit the students to gain experience in actual meaningful experimentation. Moreover, we realized that the different areas of biology are closely enough related so that mastery of the experimental method in one area equips the student sufficiently well for the experimental work in other areas. Finally, we found that the laboratory experience is most effective when the student has sufficient time to read the original literature describing the experimental method, to repeat experiments that have failed, or to devise more appropriate experiments.

Our new laboratory program is designed to deal with these problems. The chemistry laboratory, 5.31, is still required. A new 12-unit laboratory, 7.011, Introduction to Experimental Biology, has been organized. This laboratory is generally taken by Course VII students in the spring term of their sophomore year and introduces them to the methods used in biological research. We are fortunate to have the equipment available to acquaint the students with chromatography, gradient centrifugation, and the use of isotopic tracers. They carry out experiments such as the fractionation of the major components of animal cells, the measurement of growth and enzyme production by bacterial cells, and the analysis of



the composition of macromolecules. Because 7.011 is largely concerned with methodology, it does not meet the general Institute laboratory requirement. We continue to offer 7.02, Experiments in Biology, for students interested in biology but not following Course VII. Here, students have the opportunity to carry out one of several projects for two-thirds of the term, with the last third reserved for a discussion of the results.

For Course VII students, we offer over a two-year cycle four major projects: 7.031, Experimental Genetics and Microbiology; 7.041, Experimental Cell Biology; 7.051, Experimental Biochemistry; 7.061, Experimental Physiology. Each of these subjects is rated at 24 units and is meant to occupy approximately half of the students' time during the term. Course VII students are required to choose one of these four subjects. The time allotted to these subjects makes it possible for the students under the guidance of the staff to gain competence in the design, execution, and critique of experiments that are the basis of current biological research.

We have made several changes in the subjects offered for graduate credit. Newly offered will be 7.71, Biophysical Chemistry, by Professor Paul R. Schimmel and 7.73, Seminar in Immunology, by Professor Lisa A. Steiner.

#### RESEARCH

The research by members of the Department's faculty, research associates, research fellows, and graduate students is described in a publication entitled *Research Summaries*. It is available at departmental headquarters.

#### PERSONNEL

Newly appointed to the Department as Assistant Professors were Dr. David Botstein and Dr. Boyce W. Burge. Dr. Botstein, a microbiologist and geneticist, received his Ph.D. degree from the University of Michigan in 1967 and served as Instructor in this Department during the past year. Dr. Burge, a virologist, received his Ph.D. degree from Harvard University in 1966 and has been a Postdoctoral Fellow at Albert Einstein Medical School in New York.

Associate Professor Bernard S. Gould was promoted to the rank of Professor.

We were privileged to have Dr. Rita Levi-Montalcini, a distinguished neurobiologist, join our Department as Abby Rockefeller Mauzé Visiting Professor from April 3 through April 16. She presented lectures entitled "The Nerve Growth Factor" and "In Vitro Studies on the Insect Nervous System."

During the coming year Professor Phillips W. Robbins has been granted sabbatical leave to carry on research at the laboratory of Professor Michael Stoker in London, England.

Professor Maurice S. Fox was on leave of absence this year, and was in residence at the Laboratorio Internazionale di Genetica e Biofisica, Naples.

Two members of our faculty, Professors Kurt S. Lion and Francis O. Schmitt, retired this year. Professor Lion will continue his service as Senior Lecturer. He has been associated with M.I.T. since 1941, after obtaining his engineering and doctoral degrees in Germany and serving at universities in Germany, Turkey, and Switzerland. His major interest has been biological instrumentation, a subject he has taught here for many years. His distinction in this field has been recognized by the award of the bronze medal of the American Society for Physical Medicine and his appointment to give the Distinguished Lecture of the Instrumentation Society of America.

Professor Schmitt joined M.I.T. in 1941, after obtaining his Ph.D. at Washington University and serving on the faculty of that institution. He was Head of the Department of Biology from 1942 until 1955, when he was appointed Institute Professor. The present distinction of M.I.T. in the life sciences is in large measure due to his leadership. Professor Schmitt's research interests are in the area of the biophysics and biochemistry of nerves and collagen. He has devoted much of his time since 1962 to the Neurosciences Research Program, which he established with headquarters at the House of the American Academy of Arts and Sciences. The program provides a focus through conferences and publications for research in neurosciences throughout the world. Professor Schmitt is a member of the National Academy of Sciences and the Royal Swedish Academy of Sciences. Among his many honors are the Albert Lasker Award of the American Public Health Association and the T. Duckett Jones Award of the Helen Hay Whitney Foundation.

BORIS MAGASANIK

### DEPARTMENT OF CHEMISTRY

Thirty-seven undergraduates were awarded the Bachelor of Science degree in chemistry this year: two in September, two in February and 33 in June. College seniors are eligible for the draft, but the majority have been admitted to graduate schools throughout the country; six with National Science Foundation Fellowships, the others with substantial financial aid as teaching assistants. Several seniors have taken advantage of the flexible curriculum in chemistry, which provides elective time in the third and particularly in the fourth year, to prepare for advanced study in medicine, business administration, law, and the social sciences. Seven well-qualified seniors have elected to continue their education as can-

didates for two simultaneous S.B. degrees in June, 1970, in fields such as physics, electrical engineering, business administration, and the social sciences.

Degrees of Doctor of Philosophy were awarded to 18 candidates in September, 1968; 17 in February, 1969; and 14 in June, 1969. In the last few years there has been a trend toward more graduates electing further postdoctoral education in preparation for an academic career. The trend has changed this year somewhat, with a larger fraction of graduates going into industry. Some graduates received National Institutes of Health and National Science Foundation Fellowships, and some accepted academic positions.

During the year four graduate students received their induction notices and reported for duty in the armed forces. Several other graduate students managed to have their induction postponed until the end of the academic year. It appears that several of the graduate students currently enrolled in the Department or scheduled to begin graduate work next fall will be inducted during the summer.

As in previous years, approximately 70 per cent of the postdoctoral research staff are foreign nationals on temporary appointments from Switzerland, Yugoslavia, Australia, England, Argentina, Japan, Germany, Canada, Israel, Ireland, Finland, Holland, West Germany, Scotland, and France.

#### PERSONNEL

Dr. Glenn A. Berchtold was promoted to the rank of Professor. Dr. Daniel S. Kemp and Dr. Robert J. Silbey have been promoted to the rank of Associate Professor.

Professors Jeffrey I. Steinfeld and George M. Whitesides have been awarded Alfred P. Sloan Fellowships.

Professor Lawrence J. Heidt retired. He joined the Department in 1935.

Professor Glen E. Gordon resigned to accept a position at the University of Maryland.

Professor David M. Hercules resigned to accept a position at the University of Georgia.

Professor Edmund L. Gamble has been on leave of absence to teach at the Birla Institute of Technology and Science in Pilani, India.

Professor James L. Kinsey has been awarded a John Simon Guggenheim Memorial Fellowship for 1969-70. He will spend a sabbatical leave at the University of Wisconsin.

Professor David P. Shoemaker has been elected vice president of the American Crystallographic Society for 1969, and president for 1970.

Four members of the chemistry faculty and their families have served during the year as House Masters or Senior Tutors in undergraduate dormitories: Professor and Mrs. Isadore Amdur in Baker House, Professor and Mrs. Klaus Biemann in McCormick Hall, Professor and Mrs. John W. Irvine in Ashdown House, and Professor and Mrs. Silbey in Senior House.

During the last year the Department was privileged to sponsor a series of lectures with funds provided from the Arthur Dehon Little Memorial and Karl Pfister Visiting Professorships. The Arthur D. Little Lectures were as follows: Professor Herbert C. Brown presented a series of lectures entitled, "Selective Reductions," "Hydroboration," and "Synthesis via Organoboranes"; Professor Sir Ronald S. Nyholm presented a series of lectures entitled, "Some Recent Developments in Organo-Metallic Transition Metal Chemistry"; and Professor Norman Davidson presented a series of lectures, "Physical Chemistry of Nucleic Acids." The Karl Pfister Lecture series was as follows: Professor Raymond U. Lemieux spoke on "Solvation Effects on Conformational Equilibria"; Professor Donald J. Cram delivered two lectures entitled, "Invisible and Revealed Reactions" and "Conducted Tour Mechanisms for Proton Transfer along Negatively Charged  $\pi$ -Systems"; and Professor Gilbert Stork delivered two lectures entitled, "Annulation Reactions" and "Cyclopropyl Ketones and Acid Catalyzed Reactions."

Professor Shneior Lifson of the Weizmann Institute of Science was a Visiting Lecturer in the Departments of Biology and Chemistry. He presented a seminar on biophysical chemistry.

Other visiting professors and scientists were: Alicia M. Brignole, Universidad Nacional del sur Argentina; Edwin P. Przybylowicz, Eastman Kodak Company; Yury V. Voroshilov, University of Lvov, Russia; Frederick R. Jenson, University of California at Berkeley, and Richard G. Brewer, IBM Research Laboratory, San Jose, California.

#### CURRICULUM

The new two-term 2-8-2 subject sequence in chemical experimentation, which replaced the traditional chemistry laboratories in organic, physical, analytical, and the previously neglected area of modern inorganic chemistry, has been highly successful. One hundred and twenty-three students — 66 second-year, 35 third-year, and 19 fourth-year — from chemistry, biology, physics, and chemical engineering were registered for the first term, 5.31. The registration for the second term, 5.32, was 15, all from chemistry. Each subject consisted of a series of four or five relatively long experiments incorporating synthesis, purification, analysis and physical measurement. By proper selection of the experimental techniques incor-

porated into the 18 experiments, each student had a reasonably thorough exposure to many of the most important experimental procedures in chemical research.

The advantages of this procedure are (a) artificial barriers separating the areas of experimental chemistry are broken down; (b) the nature of the subject demands a constant interaction between the faculty and students and the continual devising of new experiments to reflect current research practice. Since the subject is given in a single laboratory, it has resulted in the pooling and care of equipment, the ordering of supplies, and the full-time use of laboratory space. Professors Herbert O. House, David M. Chipman, James W. Dubrin, Thayer C. French, Richard H. Holm, David N. Hume, C. Gardner Swain, and Shoemaker contributed to the classroom and laboratory, assisted by a large group of experienced graduate students. Dr. Daniel D. Traficante served as laboratory director and contributed to the success of this radical change in procedure.

The prerequisite for 5.31 is organic chemistry taken simultaneously; for 5.32 prerequisites are a second subject in organic chemistry and chemical thermodynamics taken simultaneously.

The Department of Chemistry received an undergraduate summer research grant from the National Science Foundation.

#### FACILITIES

The new chemistry building is nearing completion, but there have been some delays in construction due to strikes. The Department is looking forward to occupancy of the building in the fall of 1969.

Plans for extensive remodeling of the Department of Chemistry space in Buildings 6, 4, and 2 are progressing and work in these areas will be started in late 1969.

The Department received a research instrument grant from the National Science Foundation with which a series of small computers will be purchased. These computers will be incorporated into experiments requiring on-line computing.

The Department purchased a number of major research equipment items, among them two T60 nuclear magnetic resonance spectrometers, a spectroscopy amplifier system with accessories, a Cary spectrometer and circular dichroism accessory, a gas chromatograph, and a spectrofluorometer.

#### RESEARCH

Each year some representative reports on research in the Department of Chemistry are presented here:

The research program of Professor Biemann is mainly concerned with

the solution of structural problems in organic chemistry by mass spectrometry. This technique is used to determine the structure of compounds of biological interest, and particular emphasis is devoted to alkaloids, peptides, nucleosides, nucleotides, steroid hormones, and related compounds. Recent progress in highly automated instrumentation has led to the need for development of computer methods for the interpretation of the mass spectral data obtained in this work, and present efforts are aimed at the development of instrumental and interpretative techniques that will enable one to solve structural problems more complex than those presently amenable to conventional approaches.

In addition to the continuous application of conventional and high-resolution mass spectrometry in structure determination, investigations concerning the fragmentation of organic compounds in the mass spectrometer are carried out to further the understanding and interpretation of mass spectra. Experimental and instrumental techniques are being developed which will extend the utility of mass spectrometry, for example, to compounds of higher molecular weight and polarity as well as to the investigation of organic compounds on extraterrestrial bodies such as the moon and Mars.

Professor Hume is engaged principally in the development of sensitive and reliable techniques for determining the concentration level and chemical form of various trace constituents in the environment. Particular emphasis is being placed on anodic stripping voltammetry as a means of studying metals such as zinc, cadmium, lead, and copper at the parts per billion level in water. Application of these techniques is being made in investigations of the distribution and chemical behavior of heavy metal pollutants in fresh-water systems and in studies of the variation of concentration of naturally occurring heavy metal ions in ocean water as a function of location and depth.

Professor Irwin Oppenheim is continuing the statistical mechanical study of the relationship between macroscopic properties and intermolecular forces. He has developed a rigorous theory which relates line broadening in microwave and infrared spectra to correlation functions involving intermolecular potentials. Measurement of the width and the shape of spectral lines in gases will give information about the anisotropic intermolecular potential. He and his students are studying the scattering of laser beams from fluids and are developing theories that describe the Rayleigh and Brillouin peaks. The information contained in the spectra is extremely interesting, since most equilibrium and transport properties of fluids can be inferred from them. In particular, he is studying the effects of energy exchange between internal degrees of freedom and translational degrees of freedom. Information concerning intermolecular forces involved

in this transfer will be forthcoming. In addition, information about the short time relaxation properties fluids can be inferred from these experiments. His group is continuing its study of the effect of bound states on transport properties in dilute gases. The first density correction to the transport coefficients is extremely sensitive to the existence of these bound states.

Professor Shoemaker is working on the determination of crystal structures of complex intermetallic compounds by X-ray diffraction. Two new structures have been elucidated recently:  $\nu$ - $\text{Mn}_{81.5}\text{Si}_{18.5}$ , 186 atoms per unit cell, and Q- $\text{MnCoSi}$ , 74 atoms per unit cell. Both are orthorhombic; the former is related to the P-phase (Mo-Ni-Cr) and the latter to the cubic Laves phase.

In the last few years Professor Shoemaker has begun to study the structure of surfaces by Low Energy Electron Diffraction (LEED). He has determined the structures of the 110 cleavage surfaces of the II-VI semiconductors CdTe, and ZnTe, and ZnSe, and of the 2110 cleavage surface of CdSe; the structure of the 0001 cleavage surface of zinc; and the apparent Debye temperature as a function of depth of electron penetration. He plans to augment his surface diffraction work with Auger electron spectroscopy.

Professor Silbey and his research group have been interested in theoretical studies of the properties of molecular crystals. The effect of molecular and lattice vibrations on the absorption of light by such crystals has been investigated using various approximation methods. Using a Green's function approach, expressions have been derived for the absorption coefficient of light by a molecular crystal with one electronic band. Calculations are now under way to test this model with experiment. Another project is the description of the excited electronic states of thin crystals in order to discover how the light absorption of these crystals is affected by surfaces. The thickness dependence of the dielectric function for such a crystal is being investigated. Energy transfer mechanisms in such crystals are also being studied.

Professor William B. Walters' research has been concentrated in two areas of nuclear chemistry, radioactive decay scheme studies and chemical effects of positron annihilation. He has observed lifetimes as long as 40 nsec in synthetic zeolites and has studied the effects on zeolite lifetimes of the inclusion of various organic and inorganic gases. He has also investigated the effects of conjugated double bonds on annihilation rates.

The radioactive decay scheme studies have helped to lead to a clearer understanding of the energy levels of odd-mass Sb and I nuclei. With one and three protons respectively above the closed shell at  $Z=50$ , the similarities and differences observed in the structure of these nuclei are im-

portant clues to the understanding of near closed-shell nuclei. He has furthered the understanding of low-lying negative-parity states in odd-mass Cd and Xe nuclei, and has been unable to observe such states in odd-mass Sn nuclei.

Professor Whitesides' research interests are in organometallic chemistry. Metal ions act as catalysts or reaction components in a variety of interesting organic and biochemical reactions. The involvement of the metal atom in these reactions usually occurs in one of several ways: the metal, in serving as a center for coordination of unsaturated molecules, can assist the reaction partners to assume geometries that would be otherwise improbable; it can modify or stabilize reactive intermediates; or it can act as an oxidizing or reducing agent in electron transfer reactions. Examination of the course of reactions catalyzed by metals, particularly those involving transition metals, and of the reactions of authentic transition metal organometallic compounds offers a variety of interesting and complicated mechanistic problems, as well as the possibility of developing new, synthetically useful, reactions. Current research deals with problems in the chemistry and structure of organometallic compounds.

In particular, synthetic applications of reactions of copper (I), silver (I), nickel (II), platinum (II) and iron (II)  $\sigma$ -alkyls are being studied in detail. The thermal and photochemical decomposition reactions of these metal alkyls are topics of current mechanistic interest. In addition, oxidation of these compounds with strong oxidants, particularly molecular oxygen, appears to offer a delicate chemical probe for investigation of certain features of their structures. Studies of other oxidation reactions of organometallic compounds, of the reactions of organometallic compounds with authentic free radicals, and of the selectivity and mechanisms of oxidations using synthetic oxygen-carrying reagents are also in progress.

JOHN ROSS

#### **DEPARTMENT OF EARTH AND PLANETARY SCIENCES**

An event of note this year is the change in the Department's name from Geology and Geophysics to Earth and Planetary Sciences. This change reflects the growing diversity of interests, not only of the faculty, but also of the students. Although the past few years have seen fantastic progress, the major problems of the planets are still unresolved. However, new opportunities and novel tools are available for the study of the planets, and the Department is preparing to be an active participant in the next decade of planetary exploration. It may well be that many unsolved problems about the earth will find their solution in the first data returned from the



moon, Mars, and Venus. Faculty and students have made outstanding achievements in the fields of planetary physics and chemistry, geology, geophysics, and oceanography.

An experimental program has started in long-baseline atomic-clock radio interferometry to study small motions of the earth with unprecedented time and spatial resolution. Intercontinental drift of 10 cm a year will be detectable after a few years of observations. In addition, this technique will be used to make very precise tests of general relativity. Recent results from radar observations, in cooperation with Lincoln Laboratory staff, include the first detection of echoes from an asteroid (Icarus), and the discovery that variations in near-equatorial topography on Venus and Mercury are at most a few kilometers.

Theoretical studies of the rotation of the planet Mercury have been pursued to understand the apparent 2:3 commensurability of Mercury's spin and orbital revolution periods. Particular attention has been paid to the effects on this resonance of the large periodic changes in orbital eccentricity which are believed to occur over millions of years. The influence of a possible fluid core within Mercury has also been investigated.

The pulsar in the Crab nebula passed only  $1^\circ$  from the limb of the sun on June 14. For a month before and after this conjunction, pulse arrival times were accurately measured at the Arecibo Ionospheric Observatory to study the solar corona and the predicted effects of general relativity on pulse propagation near the sun. A continuing program of measurements has been established to provide information on the earth's orbit, and on conditions in the interstellar medium.

A detailed theoretical study of the structure and composition of the atmosphere and clouds of Jupiter and Saturn has led to a number of predictions concerning the observable properties of these planets. It is concluded that only  $H_2$ ,  $CH_4$ , and  $NH_3$  are present in spectroscopically detectable quantities above the topmost cloud layer. Four important cloud layers are predicted to occur in the upper atmosphere: solid  $NH_3$ , solid  $NH_4SH$ , aqueous  $NH_3$  solution plus ice, and solid  $NH_4Cl$ . A similar study for the atmosphere of Venus predicts multiple cloud layers composed of compounds of mercury. Recent observations reported by several astronomers are consistent with these predictions, and it is anticipated that further attempts at experimental verification will be forthcoming in the next few years.

The spectral reflectivity 0.30 to 2.50 microns of various areas of the lunar and Martian surfaces was observed using telescopes on Mt. Wilson and Mt. Palomar, California, and on Cerro Tololo, Chile. Absorption bands, which differ with surface position, were discovered in these spectra, indicating that the mineralogy of these can be explored using earth-

based observations. Spectrophotometric observations of satellites and asteroids also revealed systematic differences in the spectral reflectivity which are probably compositional in nature. The determination of the distribution of these compositional groups throughout the solar system should give information about the formation of the solar system. Moderate resolution spectra of the various bands and zones of Jupiter and Saturn were taken using the 100-inch and 200-inch telescopes on Mt. Wilson and Mt. Palomar, California. These first complete spectra throughout the spectral region 0.30 to 2.50 microns show quantitatively the color differences among the bands and zones which can be seen with the eye. A depression in the near-ultraviolet spectral region for some bands suggests compositional differences. Higher resolution studies are planned for the coming year.

Research in geochemistry has led to an examination of the global history of the crust of the earth. The distribution patterns of crustal areas of different ages indicate that two large, ancient continental nuclei appear to have increased in size by peripheral growth over the course of 95 per cent of earth history. Following this, during the short remaining period of time, it appears that these land masses split apart and moved to their present dispersed locations.

Studies of the ages of older basement rocks support a theory that the northern Appalachians are built up of two blocks which were joined by continental drift. Recognition of the possibility that the two blocks were originally separated by an expanse of oceanic crust suggest that some of the heretofore puzzling features of this ancient mountain range may be analogs of modern features such as island arc and the sedimentary prisms deposited at the junction between continental blocks and oceanic crust.

Many ore deposits are related to the volcanic process. Water has a profound effect on the temperature at which volcanoes erupt, but it is lost to the atmosphere during cooling and crystallization of volcanic lava flows. Experimental studies on the pressure-temperature relationship of water-containing minerals permit the geologist to make estimates of the physical conditions of ancient volcanic eruptions and to understand modern-day volcanic eruptions better. Specific applications have been made in the Sierra Nevada batholith, California, and in the granitic plutons of New England.

The verification of sea floor spreading and continental drift, based upon the data of scientists from many institutions and countries, represents one of the major discoveries of natural science. New sea floor is created along mid-ocean ridges. It was shown this year that the thickness of the lithosphere under these ridges is at least 65 kilometers. This is based upon a new method for the precise determination of the focal depth

of earthquakes. Using free oscillations of the earth, it was also demonstrated that the density in the lower part of the lithosphere is between 3.5 and 3.6 gm/cc. This represents the first absolute determination of density independent of equation of state assumptions. The density is so high as to indicate a gravitational instability which may be the driving force of sea-floor spreading. An hypothesis was proposed to account for the high density of the suboceanic lithosphere, in which basalt intruded on the mid-ocean ridge cools and phase converts to eclogite as the sea floor moves laterally away from the ridge.

Continental drift and sea floor spreading are aspects of a world-wide tectonic mechanism. Earthquakes are another indication of dynamic processes in the upper mantle. Evidence was obtained that a large underground nuclear explosion in Nevada triggered a simultaneous earthquake. The data was obtained on a newly designed accelerometer system specifically developed to measure the near-field motion from large underground explosions and earthquakes. Laboratory studies of shocks produced by changes in pore pressure in rock under stress have shown that materials exist which, when introduced along a fault, might convert a violent fracture into a stable creeping motion. These results open the possibility that natural faults might be modified so that earthquake activity would be less damaging.

There is accumulating evidence that the earth's mantle at depths between 100 and 200 km is partially molten. This region could be the source of volcanism and also serve as the weak layer over which continents slip. Theoretical and experimental studies are being carried on concerning the properties of such material. Theoretical studies indicate that the velocity and absorption of shear waves is frequency-dependent and that near a characteristic frequency, high attenuation and low velocity should occur. This prediction was verified in an experiment in which an attempt was made to simulate actual conditions by studying propagation in a rock containing a network of cracks and saturated with variable viscosity fluids.

A set of short period seismograms along a profile running northeast from the Nevada Test Site has been used to set limits on the structure of the upper mantle. A powerful method has been developed to interpret the data. A Monte Carlo technique is used first to generate a set of models. Synthetic seismograms are then computed for each model. Although a wide variety of models pass the travel-time tests, a comparison between the synthetic and observed seismograms allows us to reject most of the models. None of the models containing prominent low velocity zones is acceptable. The preferred models have smoothly varying upper mantles with an abrupt increase in velocity at about 400 km, which is associated with the olivine-spinel phase transition.

One of the greatest surprises in the past year in the study of the heat flowing to the surface from the interior of the earth was found in measurements in the interior lowlands of the United States. The surface flux in Iowa varies almost linearly from a high ( $1.8 \times 10^{-6}$  cal/cm<sup>2</sup> sec) in the southeast to a low ( $.4 \times 10^{-6}$  cal/cm<sup>2</sup> sec) in the northwest. It is possible that this variation is due to a major crustal break that extends from the western end of Lake Superior to Kansas.

By utilizing large seismic arrays, we have obtained new data for the earth's core which are unique and comprehensive. The structure of the earth's core, based on these data, has some features that differ significantly from previous models. A gradient in seismic velocity inside the liquid core has been found which is interpreted as an indication of crystallization of the fluid in the core. This interpretation implies that the evolution of the core is still continuing, with solidification contributing to the growth of the solid inner core and providing the energy for fluid convection in the liquid core, which is the source of the earth's magnetic field.

To shed some light on the common, but little understood, appearance of ripples on a flat sand bed in unidirectional water flow, the development of ripple trains behind isolated protuberances on the sand bed have been studied. Rather than propagating as a wave train, the study has shown that the ripples develop one by one downstream in a characteristic pattern that becomes wider and less regular downstream. In the initial stages, the ripple development can be treated deterministically, but far downstream the nature of the ripples can be described only statistically. Currently being studied to understand better the essential role of fluid turbulence in this process (ripples never develop in laminar flow) is how the course of ripple development differs for varying Reynolds numbers (turbulence intensity) given in same bed shear stress.

Oceanic sediments have been studied in several ways. Microtektites found in sediment cores near Australia have been found to be quite similar in chemical composition to tektites found on the Australian continent. The sediments found along oceanic ridges are an important part of the sea floor spreading concept. Some mid-Atlantic ridge cores have been separated into their various mineral phases. Chemical analyses of these phases have demonstrated that these cores contain significant amounts of sediment derived from the submarine mountains of the mid-Atlantic ridge. Since the sediments along ocean ridges are displaced laterally as part of the process of sea floor spreading, the sedimentary processes along the mid-ocean ridge provide insight as to the nature of sediments over most of the ocean basin.

As part of a continuing effort to understand the regional tectonics of geologically complex areas, geophysical studies have been carried out in

southern California, the Caribbean, the South Pacific, and the mid-Atlantic ridge. These studies consisted of making new geophysical measurements of gravity and magnetic fields and in the interpretation of existing data. A study of the gravity and seismic data for the South Pacific indicates an anomalous crust and upper mantle associated with the Fiji basin. Gravity measurements in southern California and the offshore area show that the continental borderland in this area has a structure more closely allied with that of a Basin and Range type than with a typical oceanic structure. A large mass deficiency associated with the southern California batholith has been interpreted in terms of a decrease in density of the batholithic rocks and an increase in the crustal thickness beneath the area. Local studies of the geophysical anomalies associated with the geothermal area in the Salton Trough are being interpreted in terms of sources for the high temperatures encountered.

The ocean telescope is an array of sensors located off the Bermuda coast and cabled to recorders on land. It was successfully placed in operation this year and has provided many months of observations on internal ocean waves, which are large fluctuations within the body of the ocean that are distant from the waves on the surface. These waves are known to exist but have rarely been observed. It is expected that the data will reveal new information on how these waves are generated and their effect on large-scale oceanic processes.

The departmental curriculum continues to undergo changes which reflect interest in improving the teaching program as well as reflecting the changing interests of the faculty. More subjects in the planetary sciences are being offered. The first-year geology subject now represents a major effort of the Department in terms of revised lectures, new laboratory programs, and pedagogical techniques. Many field trips are being organized by faculty and students to heighten the interest in regional geology and geophysics. The graduate and undergraduate student organizations have taken an active role in organizing some of these departmental activities as well as easing the transition of newly arriving students into the M.I.T. community.

Course XII-B, the S.B. degree in the physical sciences offered by the Department on behalf of the School of Science, has completed its first year successfully. This Course, which attempts to remove the traditional boundaries between departments, is becoming increasingly popular among undergraduates and is now oversubscribed. Course XII-B has primarily attracted high-performing undergraduates who wish to enter interdisciplinary fields. Course XII-B registrants have already doubled the undergraduate enrollment in the Department.

FRANK PRESS

**DEPARTMENT OF MATHEMATICS**

It is a great pleasure to begin this report by acknowledging the contributions made to the Department by Professor William Ted Martin during his 21 years as Head. Beginning with the program of C.L.E. Moore Instructorships in 1948, his leadership has strengthened the quality of an expanding department and developed the strongest possible undergraduate and graduate programs. The best tribute we can pay to Ted is to try to maintain the standards of excellence that he has set for us.

In my first year as Head, I have enjoyed the assistance and cooperation of Professor Harvey P. Greenspan, Chairman of the Committee on Applied Mathematics, and Professor Kenneth M. Hoffman, Chairman of the Committee on Pure Mathematics. The senior faculty on these committees and on the Departmental Committee have made a sizeable contribution to the administration of the Department.

At the same time, several faculty members were active in general administrative matters within M.I.T. Professor Gian-Carlo Rota served as Chairman of the Freshman Advisory Council, and Professor James R. Munkres as Chairman of the ad hoc Committee on the Academic Calendar. Professor Martin has been elected Chairman of the Faculty for 1969-70.

**CURRICULUM**

With 268 undergraduates and 118 graduate degree candidates enrolled in mathematics, the curriculum continues to be one of the Department's major concerns.

Next year we will continue to give high priority to the policy of teaching advanced undergraduate subjects in smaller sections rather than large lectures. We will also offer in both fall and spring terms several subjects which previously had been offered in only one term.

With Professor Arthur P. Mattuck in charge, the structure of freshman calculus will be considerably changed. Of the entering freshmen, more than four hundred will have sufficient preparation to enroll either in the honors version, 18.01S, of calculus, or in the second term of the regular calculus program, 18.02. About an equal number will take the regular first-term calculus, 18.01. The approximately 200 remaining freshmen will take a new subject, 18.011, which will cover the same material as 18.01 in a more simplified treatment designed for students without previous experience in calculus. This subject will be given in small sections rather than the lecture-recitation system used in 18.01 and 18.02.

Sophomore calculus is likewise scheduled to undergo revision. As a first step, Professor Louis N. Howard will offer an experimental two-term subject, 18.031-2, to a limited number of students next year. The first

term bears the title Linear Mathematical Systems, and will cover linear equations, matrices, eigenvalue problems and normal forms, and systems of linear differential equations with constant coefficients. The second term, Differential Equations, will cover existence theorems, numerical methods, linear systems with variable coefficients, boundary value problems, and perturbation theory.

In the spring term, Professor Rota will offer 18.025, The World of Mathematics, a survey of topics of current interest and of broad cultural significance, designed for students not majoring in mathematics, and stressing the central role of mathematics in today's world.

Several subjects in the theory of computers will be offered. Among these are two new subjects to be given by Professor Michael S. Patterson: 18.161, Introduction to the Mathematical Theory of Computation, for undergraduates; and 18.162, Computers and Logic, for graduate students.

#### **FACULTY COUNSELING**

Recognizing that the advising of undergraduates is of growing concern to both students and staff, the Department is changing its method of assigning faculty counselors next year. Mathematics majors will be allowed to choose an advisor from a group of 23 faculty and staff, and will be encouraged to make the choice according to the advisor's field of interest. We will try to emphasize the counselor's role as advisor by having much of the registration material handled by Professor George P. Wadsworth's office. At the same time this will allow us to keep a consistent record of the students' progress in fulfilling degree requirements.

#### **SPACE**

The urgent need for space is one of the most pressing problems facing the Department of Mathematics at this time. We presently occupy 19,200 net square feet in Building 2; 4,980 net square feet in Building 24; and 900 net square feet in Building 20. In addition to the difficulties that such widely separated space causes, we must face the fact that the total amount of space is not sufficient.

Completion of the Dreyfus Building for Chemistry and related renovations in Building 2 will result in the acquisition by the Department of a net area of 9,035 square feet in Buildings 2 and 4. A preliminary program has been drawn up for the use of this space and of space to be acquired in the future. We hope that this program can be implemented.

#### **APPLIED MATHEMATICS**

Applied mathematics at M.I.T. means the mathematical study of general scientific concepts, principles, and phenomena. Emphasis is placed on the interpretation of the subject as a science because the primary goal is

knowledge about the real world. The core of the program consists of research and a complete curriculum covering the following important scientific principles and their mathematical formulations: propagation, equilibrium, stability, optimization, cybernetics, and random processes. The subjects that receive explicit study and elucidation include: fluid dynamics, solid mechanics, astrophysics, geophysics, wave motion, turbulence, kinetic theory, statistical mechanics, particle physics, probability, combinatorics, artificial intelligence, automata, computation, control, learning theory, analysis, and mathematical methods.

The characteristics and objectives of applied mathematics are breadth, versatility, innovation and approximation, and a concern with fundamental concepts of interdisciplinary importance. The program stresses recognition and exploitation of important analogies and transference of methods and techniques from one field to another. The results of such an effort will counteract the trend towards narrow specialization and stimulate an effective and productive dissemination of mathematics throughout science and technology.

The faculty and student body in applied mathematics have increased rapidly in the last few years. Two laboratories, for computation and continuum mechanics, are presently in operation, and the academic curriculum has been completed with the introduction of several new undergraduate subjects. The growth of applied mathematics as a separate discipline and its federation with pure mathematics has given M.I.T. a balanced, distinguished, and assuredly unique Department of Mathematics.

#### AFRICAN MATHEMATICS PROGRAM

Three members of the Department have been active in the African Mathematics Program, carried out by the Education Development Center with financial assistance from the U. S. Agency for International Development and the Ford Foundation. The purpose of the program is to develop and introduce into the schools of tropical Africa mathematics curricula that are related to the development needs of Africa. The program has conducted annual workshops each summer since 1962 in Entebbe, Uganda, and Mombasa, Kenya. These workshops with participants from ten African countries have produced mathematics textbooks, teachers' guides, and related examinations for both elementary and secondary schools. The program has also been engaged in the training of teachers as well as mathematics tutors in the teacher training colleges. This has been done at three summer institutes held at Nairobi for representatives of the various countries and also various teacher training institutes held within the individual countries. At the final workshop held in July and August of 1968, the program completed the preparation of textbooks for use throughout



the primary and secondary school system. This included 19 textbooks at the primary level, 36 at the secondary level and four devoted to teacher training. A total of more than four hundred thousand copies of these texts have been distributed for use in the participating countries.

Professor Martin was one of the founders of the African Mathematics Program, and has served as Chairman of the Steering Committee. Professor Hartley Rogers has participated in the Mathematics Workshop of the program for the past four summers, and served as co-chairman of the Secondary Writing Group during the last two summers. Professor Mat-tuck was one of the writers in this group.

#### RESEARCH

With few exceptions, the faculty and staff of the Department are actively engaged in research. Among the fields being pursued are algebra, algebraic geometry, real and complex analysis, astrophysics, combinatorics, theory of computation, differential equations, differential geometry, functional analysis, hydrodynamics, Lie groups and representations, logic, mathematical physics, number theory, numerical analysis, probability, statistical mechanics, and topology. A complete description of the individual research of each member of the Department cannot be given here, but a report of the recent work of a few faculty members will serve as an illustration.

Professor Donald W. Anderson has been active in algebraic topology, especially K-theory. Last summer he was invited to give a series of lectures, "The Foundations of K-theory," to the Nordic Mathematics Summer School in Aarhus, Denmark.

Professor Prescott D. Crout has derived mathematical procedures for calculating radar target return. The cases which are of primary interest are those in which the antenna pattern used for the transmitter differs from that used for the receiver, and neither necessarily has plane polarization.

Professor Sigurdur Helgason has obtained a fairly complete solution of the problem of determining the so-called conical distributions. These are distributions on the horocycle space of a symmetric space with certain invariance properties. Several applications to representation theory of semisimple Lie groups have been worked out. Professor Helgason reported on this work in an address at the Scandinavian Mathematical Congress in Oslo in August, 1968.

Professor Christopher Hunter has been studying the large-scale modes of oscillation of flattened galaxies. A relatively simple system of equations describing the motion of the stars of the galaxy has been formulated, and its properties are now being investigated.

Professor Daniel J. Kleitman is continuing his study of asymptotic enumeration of combinatorial structures, and of size limitations on such structures produced by simple algebraic restrictions. He is also studying various packing problems as well as some practical network flow and multicommodity flow problems. He has reported on these studies in invited addresses at the Conference on Combinatorics and Applications at Calgary, Alberta, and at the Symposium on Network Analysis in Washington, D.C.

Professor Bertram Kostant has developed a unified picture for obtaining the irreducible unitary representations of Lie groups. The theory is based on a differential geometric approach, inspired by the work of Kirillov, and uses symplectic manifolds, line bundles on such manifolds, polarization, and a rigorous notion of quantization. Recently, Professor Kostant has been working to relate this theory to the more classical analytic approach to representation theory. He is engaged in writing a book on this subject.

Professor Elliot H. Lieb has continued his work in statistical mechanics and solid-state physics with particular emphasis on exact results and solution of models. He has presented invited addresses at the Symposium on Exact Results in Statistical Mechanics at the University of California at Irvine in 1968 and the Fourteenth Solvay Chemistry Conference on Phase Changes in Brussels in 1969.

Professor Chia-Chiao Lin has been studying, in collaboration with Dr. Chi Yuan and William W. Roberts, the implications on astronomical observations of the density wave theory for galactic spirals, previously developed by himself and Frank H. Shu. The theoretical predictions agree very well with observational data. Professor Lin has been invited to address the American Astronomical Society in August, 1968, an International Symposium on the Structure of our Galaxy, in 1969, and the General Assembly of the International Astronomical Union, to be held in 1970.

Professor Mattuck has been working in two general areas in algebraic geometry. One is the study of a class of isolated singularities of algebraic surfaces that are characterized geometrically and cohomologically, and include the rational singularities. The other is a group of theorems relating the properties of a surface and its symmetric products, a typical one being that a surface is ruled if and only if the generic fiber of the Albanese fibration of its symmetric product is rational.

Professor Daniel B. Ray and Professor Isadore M. Singer have been jointly studying a manifold invariant defined in terms of the zeta function of the laplacian on differential forms. A program is under way to relate this invariant to a combinatorial invariant, the R-torsion. The work has led to the investigation of other similarly defined invariants.

Professor Eric Reissner has obtained new results on nonlinear elastic

shell theory and on the theory of shallow shells. He has initiated work on postbuckling behavior and imperfection sensitivity, leading to some new results and simpler access to some known results.

Professor Rogers has continued his research on higher recursion theory, including axiomatizations of generalized recursion theory and category-theoretic aspects of such axiomatizations.

Professor Rota has completed the manuscript of a book, *Combinatorial Geometries*, in cooperation with Professor Henry Crapo of the University of Waterloo, to be published by The M.I.T. Press. His work in combinatorics also includes studies of Baxter algebras and combinatorial identities, and of Möbius functions and the Euler characteristic.

Professor Irving E. Segal's research in functional analysis involves interrelations between operator theory in Hilbert space, evolutionary partial differential equations, integration in function space, and group representation theory. Applications are being made to questions in theoretical physics. Professor Segal has presented invited addresses at the Symposium in honor of Professor Salomon Bochner at Princeton University, at the Colloquium on Applications of Mathematics to Modern Physics at Washington, D.C., and at a Conference on Mathematical Methods in Physics at the University of North Carolina.

Professor Frederic Y.-M. Wan has continued the investigation of problems involving unsymmetric stress distributions in the theory of helicoidal shells. He has extended the concept of static geometric duality of linear shell theory and made it computationally useful. He has also collaborated with Professor Reissner in establishing a generalized shallow shell theory.

#### PERSONNEL

Professor Isadore M. Singer was awarded the Bocher Memorial Prize by the American Mathematical Society at its 75th annual meeting held in New Orleans in January. The Bocher Prize was awarded to Professor Singer for his joint work with Professor Michael Atiyah of Oxford University on the index theorem. This theorem relates analytic and topological definitions of the index of a differential operator on a manifold; its proof called for the use of the intricate techniques of analysis and topology.

During the past year, Professors Donald W. Anderson, Manuel Blum, Roe W. Goodman, Louis N. Howard, Takeshi Kotake, W. Ted Martin, Daniel G. Quillen, Eric Reissner, Richard D. Schafer, and Isadore M. Singer were on leave of absence for the year, and Professor Warren Ambrose for part of the year. Professor Ambrose was at the State University of New York at Stony Brook. Professor Anderson, who held an Alfred P. Sloan Research Fellowship, remained in this area. Professor Blum was Visiting Assistant Professor at the University of California at Berkeley.

Professor Goodman spent the year at the Institute for Advanced Study in Princeton. Professor Howard was Visiting Professor at the University of California at Los Angeles in the fall term and was at the Royal Institute of Technology in Stockholm in the spring. Professor Kotake, on a Guggenheim Fellowship, was at New York University in the fall and at the University of Paris in the spring. Professor Quillen held an Alfred P. Sloan Research Fellowship, and visited the Institute des Hautes Etudes Scientifiques in Paris. Professor Reissner, with a National Science Foundation Senior Postdoctoral Fellowship, was at the University of California at San Diego. Professor Schafer spent the year at the University of Chicago. Professor Singer, who held a Guggenheim Fellowship, spent the year at Oxford University.

As Visiting Professors last year we were fortunate to have Professor Seymour A. Papert, Professor Lajos Pukanszky of the University of Pennsylvania, Professor Robert Steinberg of the University of California at Los Angeles, and Professor Ved P. Mainra of the Birla Institute of Technology.

Professor Radha G. Laha of Catholic University spent the year with us as a guest.

We are pleased to report that Professor Willem V. Malkus of the University of California at Los Angeles and Professor Seymour A. Papert will be joining our faculty next year as Professors of Applied Mathematics. Other new faculty members are Associate Professor Steven Kleiman and Assistant Professors Rodney J. Baxter, Michael Fischer, Philip J. Greenberg, and Michael S. Patterson.

We regret to report the resignations of Professors James G. Glimm, Victor Barcion, Manuel Blum, Norman Bleistein, and Colin J. Thompson. Professor Glimm has accepted a position as Professor at New York University. Professor Barcion will be at the University of California at Los Angeles, Professor Blum at the University of California at Berkeley, Professor Bleistein at the University of Denver, and Professor Thompson at Northwestern University.

Professors Victor W. Guillemin, Stephen Grossberg, and Harold M. Stark have been awarded Alfred P. Sloan Foundation Fellowships for next year.

NORMAN LEVINSON

### **DEPARTMENT OF METEOROLOGY**

As so often happens, the effects of the research funding stringencies and the dropping of draft deferments for graduate students have not proven

to be as serious as was anticipated a year ago. What has actually happened is that both the number of students and the sponsored research support have been very much the same this year as last. Because of inflation, level funding means a decrease in the research effort. The continuing decline in the number of fellowships available to our students has required us to provide more research assistantships. The necessary savings have been accomplished by reductions in the supporting staff and in postdoctoral research appointments. The net effect has been a slowing of the rate of research progress with no change in the scope of the research. It is hardly necessary to say that it has not been feasible to seek support for new research undertakings.

Some 90 per cent of our graduate students are candidates for the doctorate, a proportion that is typical of a science department. However, this reflects a significant change that has taken place over the past decade. Earlier, the Master of Science was the terminal degree sought by half or more of our students. I take this to be another indicator of the rapid development and increasing maturity of the sciences of the atmosphere and of the oceans. It is interesting to note that ten doctorates were awarded during the year as compared to five in each of the two preceding years. With a stable enrollment it is likely that eight to ten doctorates will be awarded each year.

The evidence available to me suggests a decrease of perhaps 10 per cent in enrollment next year. The number of applicants was smaller than a year ago, although their quality remained high. It is my impression that a number of potential applicants decided to seek employment where they might anticipate occupational draft deferments. There may also be an impression that funding restrictions have reduced the opportunities for employment in meteorology and oceanography, although there is no real evidence that this is true as yet.

In addition to the usual changes in the content of subjects of instruction that reflect recent developments, there have been a few more substantive changes. Professor Robert C. Beardsley developed a new graduate subject, Surface and Internal Waves, which he gave for the first time this year. Professor Peter B. Rhines began the development of a new subject on longer waves in the atmosphere and the oceans by offering it as a special subject. Professor James M. Austin developed a new subject which replaces 19.003, Elementary Meteorology, and 19.02, Descriptive Meteorology. This new subject is an elective open to both freshmen and upperclassmen and is designed to give a sound one-term introduction to meteorology that can be used also as a preparation for more advanced subjects. This subject was very well received and enrollment approached the maximum permitted by the available laboratory facilities. Professor Edward N. Lorenz

modified his regular subject, Statistical Problems in Meteorology, so as to give an extensive treatment of the theory of predictability. This has been a major research interest of Professor Lorenz in recent years and his findings have received world-wide attention.

The meteorological seminar series arranged and directed by Professor Reginald E. Newell brought our students into contact with a number of distinguished scientists both from this country and abroad. A central theme of this year's series was the remote probing of the atmosphere by a variety of means.

We have not remained aloof from the student unrest and concern that has been prevalent during the year. Both the students and the faculty have adopted a mature and thoughtful approach to the difficult and pressing problems that often lead to emotional reactions. In part this is doubtless due to the feeling that meteorology and oceanography are inherently international and that their applications are more likely to benefit than harm mankind. I also like to think that the close contact between our students and faculty has led to genuine mutual understanding and respect. During a meeting of the Department on one of the Agenda Days, it was generally agreed that meteorologists had some special responsibilities in the area of air pollution.

Meteorologists have a special concern for the effects of global air pollution by carbon dioxide and by airborne particulates on weather and climate. Such effects are still too small for reliable detection, but the rapidly growing concentration of these pollutants and the possibility that they could cause irreversible changes in climate demand an accurate prediction of the effects while there is time to take countervailing action. This will require a more nearly global weather observing system, continuous measurements of the pollutants at selected places, and further research on the response of the atmosphere to the changes in the radiation balance that are caused by these pollutants.

The more apparent urban air pollution presents complex problems, the solutions to which will require the cooperative efforts of those from many disciplines, agencies, and political entities. Meteorology is one of the disciplines involved but, by itself, can offer no solutions to urban air pollution. Recognizing that the requisite cooperation requires some knowledge of the other areas involved, a group of students, aided by faculty, have arranged a series of informal seminars with invited speakers representing toxicology, engineering, and the state legislature.

The joint graduate program in oceanography with the Woods Hole Oceanographic Institution, in which we participate with the Department of Earth and Planetary Sciences, has had a successful beginning. Several regular subjects in oceanography were given at Woods Hole during the

summer of 1968. Some of the subjects were taught by Woods Hole staff and some by M.I.T. staff including Professors Erik L. Mollö-Christensen and Rhines. All of the entering graduate students in oceanography were invited to attend the summer session at Woods Hole and were offered the necessary financial aid. It was generally agreed that the program was successful. During the fall term 1969-70, the Woods Hole Oceanographic Institution will offer several subjects, all scheduled on two days so as not to conflict with subjects the students will take at M.I.T. This will broaden the educational opportunities of the students and will also permit them to become familiar with the facilities and staff at Woods Hole early in their academic careers.

As already noted, funding restrictions have caused some reduction in the research activities of the Department, but it is still a large and flourishing enterprise. I find it unsatisfactory to attempt a summary of the research in progress in these pages. Instead I will make a few almost incidental comments. It has become clear that some rather large-scale experimental and observational projects must be undertaken in order to seek answers to certain crucial questions concerning the atmosphere, the ocean, and their interactions. One of the first of these large undertakings is the Barbados Oceanographic and Meteorological Experiment (BOMEX), which is being carried out during the spring and summer of 1969 in the Caribbean. The objectives of BOMEX are to study the atmosphere and oceans and their interactions in this subtropical area, which is a part of the principal source of heat and water vapor for the atmosphere. During the last few years Professor Jule G. Charney has developed a new theoretical picture of the behavior of the tropical atmosphere. During the latter half of BOMEX the extensive array of ships, aircraft, and buoys will be reoriented to collect the data needed for confirmation of Professor Charney's theories, and he will actively participate in and guide this program on the site.

On a smaller scale than BOMEX, Professor Mollö-Christensen and his students spent last summer at the Buzzards Bay Entrance Light Station (a "Texas" tower), measuring the details of the interaction between the ocean and the air. Of the many novel results obtained, one of the most fascinating was the quantitative measurement of the effects of an oil slick. The slick was found to de-couple the air and the sea effectively by suppressing the capillary waves of wavelength of the order of a centimeter. Thus we now have scientific confirmation of the proverbial effect of pouring oil on troubled waters.

In accordance with another proverb regarding the beating of swords into plowshares, Professors Delbar P. Keily and Mollö-Christensen have been converting obsolescent missile systems into peaceful research tools. Professor Mollö-Christensen has converted part of the ground control

equipment of an Atlas missile system to a very versatile data-handling array for his air-sea interaction studies. Professor Keily is using parts of the inertial guidance system of the Atlas missile in a free-falling oceanic probe which is designed to record the horizontal current velocity as a function of depth.

Omission of specific references to the research of other members of the faculty does not indicate that it is of lesser significance but only that I have chosen to show a few snapshots rather than attempting a comprehensive review. Invitations to members of our faculty to make key contributions at all of the significant scientific meetings at home and abroad are ample testimony to their outstanding research achievements.

HENRY G. HOUGHTON

## **DEPARTMENT OF NUTRITION AND FOOD SCIENCE**

### **CURRICULUM DEVELOPMENT**

The graduate curriculum in both nutritional biochemistry and metabolism and in food science and technology has undergone extensive review and revision. The result is that the undergraduate program of the Department in the life sciences has also been made more flexible and more attractive to undergraduates.

### **RESEARCH PROGRAMS**

#### **FOOD SCIENCE AND TECHNOLOGY**

Research in food science and technology at M.I.T. continues to be characterized by its interdisciplinary approach and an emphasis on integration of different aspects of human food supply. This applies not only to the combination of fields as diverse as biology and engineering, but also to the effort to utilize theoretical understanding of mechanisms in formulation of practical solutions. The interdisciplinary approach here is also much more than collaboration of experts in different fields, since most of the faculty in food science and technology are not only specialists in a given discipline like microbiology or analytical chemistry, but are also generalists in the sense of understanding the full range of considerations in food science and technology. Several major areas are actively being investigated, each of which involves several faculty members.

In the field of chemistry of trace compounds in foods, including flavors, Professors Emily L. Wick, Phillip Issenberg, and James K. Palmer have continued research aimed at understanding the role of these compounds in various aspects of food quality. Their studies go far beyond detection and quantitative analysis of trace compounds, and involve work on bio-



synthetic pathways, reactions, and physical interactions of these compounds in food systems.

In the area of chemistry of food deterioration, active research continues under the direction of Professors Marcus Karel, Theodore P. Labuza, and Steven R. Tannenbaum. The work is concentrated on mechanisms and kinetics of deteriorative reactions in dehydrated and other low moisture systems. Nonenzymatic browning, lipid oxidation, and other reactions are being explored, with the present emphasis being on interactions between lipid oxidation products and proteins. The theoretical work on mechanisms parallels exploration of methods to control deterioration through application of chemical agents and/or protective packaging.

In the quantitative aspects of food science and technology, work continues in the area of physical and physicochemical properties of foods, and the utilization of knowledge of these properties in food process design and/or improvement. This work, which involves Professors Samuel A. Goldblith, Daniel I. C. Wang, Karel, and Labuza, has been concerned primarily with properties pertinent to heat and mass transfer in foods, including dielectric, thermal, sorption, and diffusional properties.

The food science and technology faculty is also playing a major part in the departmental program on new protein sources, and in particular single-cell proteins. The faculty involved are concerned with microbiological aspects, including production of the organisms; chemical aspects, including safety; and engineering aspects of the problems. Professors Anthony J. Sinskey, Tannenbaum, and Labuza are particularly involved in this area.

In the field of microbiology and virology of foods, active research continues under the direction of Professors John T. R. Nickerson, Goldblith, and Sinskey, and Dr. Joseph J. Licciardello, in collaboration with others. The principal projects involve the use of various forms of electromagnetic energy to eliminate hazardous microorganisms, and investigation of mechanisms of microbial resistance to various lethal and sublethal agents. A program in tissue culture and in food virology is also under extensive development.

#### NUTRITIONAL BIOCHEMISTRY AND METABOLISM

Research in this area continues along the lines established some years ago, the major emphasis continuing to be elucidation of mechanisms involved in the control of metabolic function in terms of adaptation to environment. In general, the existing programs have been maintained and have become more focused in the area of protein utilization and metabolism. However, the concept of a continuum in research from the subcellular to the whole organism remains the dominant approach to these problems.

At the level of nuclear and cytoplasmic regulatory mechanisms, research on the role of amino acids in the regulation of protein synthesis is still in progress. Studies of polysomal integrity as influenced by amino acids and hormones continue. The way in which the synthesis of specific protein molecules are controlled is now being examined using some newly developed techniques. In addition to rodent tissue, this work is being extended to human placental tissue. Similar approaches are being used in the investigation of the ontogenesis of protein synthesis in neonatal animal tissues. This work has already defined polysomal stability as one significant control point in this process and has indicated the possibility of two different kinds of polysomes being involved. The central role in this process of dietary modifications in amino acid pools is also being explored.

Similar studies using Vitamin A as a control point are also continuing. Moreover, these studies, which have as their goal the understanding of the role of Vitamin A in metabolism, are concentrating on the area of protein synthesis, particularly in the intestinal mucosa. In addition to the liver and intestine, the muscle mass also is under investigation at the subcellular level. Finally, using a different approach, these mechanisms are being examined with the aid of certain toxic components of the environment. Not only will this help to demonstrate the way in which these environmental toxicants work, but it will also aid in understanding the mechanisms of the regulation of protein synthesis.

The interaction of the animal and its environment continues to be examined from the viewpoint of cyclic variation. Studies of the control of diurnal cycles in enzyme activity and in the role of catecholamines in this regulation continue to be a central concern. These are performed using molecular, organ, and whole animal approaches. More recently, they have been extended to the neonate.

At the organ level, studies of the role of diet in the maintenance of the oral tissues are in progress. However, more emphasis is being placed on the cellular and subcellular changes underlying the gross observable effects. In addition, the interaction of the oral flora and the chemical components of the oral cavity is being explored.

At the whole animal and clinical level, areas of research defined in the subcellular studies are being extended to the human. The influence of infection, exercise, and unconventional dietary components continues to be a major area of research. Where appropriate, the studies are integrated with those using animal models. Work on lipoprotein regulation and purine metabolism are examples of this approach.

It is apparent that the research in the area of nutritional biochemistry and metabolism continues to be oriented in the area of control and adaptation with specific reference to protein metabolism. This is best expressed

using the general interest in development that occurs in all aspects of departmental research. This work ranges from studies of subcellular regulation to examination of the role of diet in neonatal life to development of specific organs and structures, including those of the oral cavity.

In addition to the general theme of development, there continues to be great emphasis placed upon studies designed to alleviate nutrient deficiency throughout the world. Most interest is being expressed through the studies of single-cell protein being performed with the groups in biochemical engineering and in food science. More recently, the effect of high nucleic acid diets has been examined both in the human adult and in the neonatal rat. In both cases, evidence of possible metabolic derangement has been obtained. These areas continue to occupy a significant place in the research programs.

In general, therefore, research in nutritional biochemistry and metabolism ranges from the subcellular to the clinical, from the neonate to the aged, from the academic to the applied. Its central theme continues to be the understanding of the way in which the living organism adapts to, is controlled by, and is regulated in its environment, with nutrition as the environmental factor that is our central concern.

#### BIOCHEMICAL ENGINEERING

The research activities in biochemical engineering cannot be categorized as one discipline. Many of the programs are conducted jointly with faculty members in nutrition, food science, and chemistry. The guiding principle in biochemical engineering research is the integration of basic knowledge from microbiology, biology, biochemistry, chemistry, and engineering.

Research on continuous culture methods has expanded in scope from the previous years. One of the topics being examined is the dynamic behavior of continuous culture on multiple substrates. In these studies the chemostat is operated with one substrate limiting and simultaneously keeping a second substrate close to limitation. Dynamic response of the organism is then analyzed by reversing the condition of substrate limitation. The results from these experiments will yield data pertaining to biosynthesis of proteins, nucleic acids, and enzyme systems.

Other areas of continuous culture research deal with the utilization of hydrocarbons by a thermophilic bacteria previously isolated in our laboratory. Studies performed at 55° C and higher are in progress to obtain a better understanding of the microbial growth kinetics and of the quantitative cellular conversion efficiencies. In addition to these studies on hydrocarbons as part of the overall single-cell protein program, other continuous culture experiments are in progress with bacteria and yeasts. These chemostats are being operated to test various chemical, physical, and

physiological conditions to upgrade the protein quality and to decrease the nucleic acid content of single-cell proteins.

Mixed microbial cultures, capable of utilizing hydrocarbons in batch and continuous systems, are also being examined to determine the kinetics of growth and substrate utilization. The objectives of the mixed cultures studies are to increase the substrate conversion efficiency and simultaneously to obtain more favorable growth conditions than those that may be achieved in pure culture systems.

A small-scale pilot plant continuous culture unit has been designed and partially constructed. With this unit, sufficient quantity of single-cell protein cultivated on various types of substrate can be produced for nutritional and animal feeding studies.

As a continual effort in the area of mass transfer in fermentation technology, research in aeration and agitation in microbial systems is being actively pursued. Mass transfer studies from single bubble to microbial cells have been performed, utilizing a flow cell which is a well-defined fluid dynamically. These experiments were performed to examine whether microorganisms possess an active transport system for transferring dissolved oxygen during cellular biosynthesis. Findings from these studies have yielded increased mass transfer coefficients in the presence of microorganisms. However, this increase was conclusively demonstrated not attributable to an active transport system but rather to a decrease in the boundary layer resistance to mass transfer. Other mass transfer studies in fermentation systems search for more efficient gas-liquid contactors, especially for the production of single-cell protein.

Laboratory studies are partially completed on an "airlift" fermentation unit which does not rely on mechanical agitation. Optimization studies have revealed that an efficient airlift fermentor should be a large height-to-diameter column containing a center draught tube. Mass transfer coefficient to horsepower relationship from this unit has been demonstrated to be extremely favorable. Sufficient mass transfer data during microbial cell growth cultivated on carbohydrate, as well as hydrocarbons, have been gathered in this unit to enable us to determine optimum geometric configurations in terms of process scale-up.

Encouraged with the laboratory findings of the airlift fermentor, a pilot-scale version has been designed, constructed, and is presently being tested. The pilot plant unit has an operating liquid volume of approximately 200 liters. This represents a volume scale-up ratio from the laboratory of approximately 30 to 1. Results from the pilot scale unit will enable us to verify and elucidate further the mechanism of mass transfer as well as to determine the pertinent parameters for further process scale-up.

A project has been in progress to examine methods of increasing re-

covery efficiency of suspended solids. Preliminary experiments have been devoted to determining the effect of chemical and physical treatments to increase the cell settling rates. In addition, many natural and synthetic flocculating agents have been screened in evaluating their roles in enhancing cell settling. Several anionic flocculants have proved capable of increasing the rate of settling tremendously. Further studies will be performed to elucidate the mechanism of flocculation as well as to obtain optimum process conditions.

One other general area of the research activity in biochemical engineering is the biosynthesis of aflatoxin by *Aspergillus flavus*. Radioactive, labeled aflatoxin has been prepared from resting cell cultures for Professor George H. Büchi of the Department of Chemistry. Chemical degradation of these labeled materials has been performed by Professor Büchi, and potentially radioactive intermediates of aflatoxin have been prepared. These intermediates will be examined in resting cell cultures in order to elucidate the pathway of aflatoxin biosynthesis.

Two research projects being carried out jointly by Professors Sinskey and Wang are in progress to study various aspects of mammalian tissue culture systems. One deals with the potential application of ultrahigh temperature techniques for sterilizing tissue culture media. The other involves the role of shear stresses on the degree of damage to mammalian cells.

#### SINGLE-CELL PROTEIN RESEARCH

Through a major grant from the Alfred P. Sloan Foundation, a multidisciplinary program on single-cell protein has been initiated. The research has been subdivided roughly into a number of areas which broadly indicate the scope and extent of our research effort.

#### ENGINEERING AND FOOD TECHNOLOGY

**CELL PRODUCTION AND RECOVERY** The aeration and agitation requirements for adequate transfer of oxygen in the continuous production of single-cell protein are known to be extremely demanding. Furthermore, the oxygen requirement for single cells cultivated on hydrocarbon is several times greater than that for carbohydrate substrates. Completed studies in our laboratory on the conventional stirred fermentation vessels show an extremely unfavorable mass transfer power relationship at high oxygen transfer rates. Initial exploration is based on a fermentor design without mechanical agitation. Preliminary results thus far on a laboratory unit show extremely favorable mass transfer characteristics.

Studies in the general area of single-cell recovery from the fermentation broth have been initiated. The main objectives of these studies are:

to determine methods for increasing cell separation efficiency; to determine mechanisms in the enhanced cell separation; and to determine engineering parameters necessary for scale-up of cell separation processes. Experiments have been performed using yeast (*Candida intermedia*), grown on glucose and normal paraffin. Methods which are being investigated to increase the cell separation efficiencies include heat treatment, pH adjustment, addition of inorganic salt, and the addition of flocculants. Preliminary results indicate that yeast cells grown on glucose and hydrocarbon can be induced to settle many times faster by the addition of either synthetic or natural flocculating agents. Detailed studies on the optimization of the recovery process with the incorporation of flocculants will be carried out.

**CELL PROCESSING** Little or no data are available in the literature on the properties of yeast or bacteria which would allow design of optimal processes for concentration, dehydration, or other processing. Therefore, studies have been initiated, using yeast as a model (initially *S. cerevisiae*), on physical properties of yeast suspensions at various concentrations and on response to various process conditions. The initial investigations have been designed to measure fluid-flow properties and densities of yeast suspensions, and thermal conductivity and bulk density of yeast powder. Studies are also in progress on vacuum concentration and air, drum, and spray drying of yeast suspensions. In each of these cases observations are being made on color, flavor, final viable cell count, and various physical and chemical properties of the finished product.

Based on evidence collected in the clinical phase of the single-cell protein project, it would appear that the relatively high nucleic acid-to-protein ratio found in yeast and bacteria might be a potential barrier to its utilization. Therefore studies are being conducted on development of the fundamental information required to design a process for reduction of cell nucleic acid content. Initial studies are being conducted in yeast (*C. intermedia* and *C. utilis*). Preliminary experiments indicated that leakage of nucleic acid degradation products in cells grown in batch culture is markedly dependent upon the physiological conditions of the culture. Therefore a continuous fermentation unit has been set up to produce yeast cells for these studies. Experiments are currently being conducted to determine optimum conditions of pH and temperature for this process. It has already been shown possible to increase the nucleic acid-to-protein ratio from 6/1 to 10/1 (25/1 for liver). At the same time, a chromatographic system is being set up to give information on the composition of the material which leaks from cells under a variety of conditions, and this information will be fed back into the process design.

## CELL AND ANIMAL BIOLOGY

**STUDIES IN MICROORGANISMS** The variation of cell composition with respect to protein content and amino acid pattern has been a subject of investigation in both yeast and bacteria. Currently, it is hypothesized that most of the variation in amino acid composition may be accounted for in terms of changes in the cell wall content and composition. Preliminary results show that in batch culture, significant variation occurs as a function of phase and age of the culture. These studies will be carried out under more controlled conditions, and also in a continuous culture apparatus. Measurement of the macromolecular composition of the cell (protein, nucleic acids, and polysaccharide) and amino acid patterns will be made in chemostat culture limited by several different nutrients and operated at varying dilution rates. The effect of a double nutritional restriction on the cellular composition will also be investigated.

Investigations are continuing on the thermophilic hydrocarbon-utilizing bacillus isolated at M.I.T. The organism is being characterized for ability to grow on various normal paraffins. Recent investigations have demonstrated that the stock hydrocarbon culture can be resolved into two different strains by purification on carbohydrate media. These strains have different biotin requirements and each is being tested for its individual ability to grow on hydrocarbons. The original culture has the peculiar characteristic of growing better on dodecane than hexadecane in shaken flasks, but equally in static culture, and studies are in progress to explain this phenomenon.

**STUDIES IN ANIMALS** During the past year, work has been centered in two principal areas. These have been concerned with the determination of the nutritive quality of the M.I.T. thermophile in young growing rats, and with the effect of nucleic acid feeding on the growth and development of the neonatal rat.

In the first study the results indicated that this organism was deficient in methionine and had a biological value of about 60. More interesting was the observation that all of the energy available for metabolism could be accounted for by the amino acid component of the cell, suggesting that the cellular lipid and carbohydrate were not in forms available for use. In addition, it appears that the non-protein nitrogen fraction is also not available for use by the animal.

The second investigation was prompted by the proposal to use single-cell protein preparations in formulae for infant feeding. Since earlier work in this laboratory had indicated a sensitivity of the neonate to purine feeding, it was decided to investigate the effect of dietary nucleic acids on growth and development in the neonatal rat. Since a soluble product was

required, an oligonucleotide preparation was used as a source of nucleic acid material. The material was included in a diet simulating rats' milk and was fed four times a day to suckling rats. The results of the study demonstrated the toxic effects of such additions to the neonatal diet. At levels of nucleotide equivalent to feeding single-cell protein as 25 per cent of the daily protein intake, weight gain was depressed by 35 per cent. At levels equivalent to 100 per cent of the daily protein intake as single-cell protein, growth was retarded to 50 per cent of the controls, and mortality was high. That these effects were not due to a simple decrease in protein intake as a result of the substitution of nucleotides for protein was indicated by the fact that animals fed a diet containing the same concentration of protein as that in the high nucleic acid diets grew significantly faster than the experimental groups. In both nucleic-acid-fed groups, kidney size per unit of body weight was increased. In general, the overall effect appeared to be an inhibition of development, since in many respects the animals resembled less mature neonates. This work is continuing and will include biochemical and morphological examinations. In addition, the effect of single-cell protein feeding to the mothers during gestation and lactation will also be examined.

#### CLINICAL STUDIES

Torula yeast has been used in small quantities in the human diet for many years, but has not been evaluated as a major protein source. Commercial dry Torula yeast (Lake States Yeast Company, Rhinelander, Wisconsin) containing 6 to 8 per cent RNA was fed to M.I.T. students in addition to their usual diets for 6 to 11 weeks. Urinary excretion of uric acid increased variably with yeast feeding. The expected percentage recovery of urinary uric acid decreased with increased yeast nucleic acid intake. The data indicate that while subjects showed a capacity partially to compensate for the increased nucleic acid intake by increased elimination via the kidneys, the mechanism is not sufficient to allow the continued consumption of large amounts of yeast unless the nucleic acid content could be lowered. The effects on serum and urinary uric acid levels of graded levels of protein intake are being evaluated. Studies are also being conducted to determine the proportion of individuals in a population with susceptibility to symptoms of gout even from small increases in dietary nucleic acid.

The quality of single-cell protein for young adults is being evaluated. The classical experimental designs used in the determination of net protein utilization and biological value have been reevaluated in order to develop an efficient and reliable method for the evaluation of protein quality in man. Preliminary results suggest that the digestibility of yeast



protein is high when fed just under the minimal protein requirement, and the biological value of yeast protein is fairly good.

#### NEW FACULTY

Dr. Arnold L. Demain will join the Department as Professor of Industrial Microbiology on July 1, 1969. He came from the Merck Sharp and Dohme Research Laboratories, where he was head of the Fermentation Research Department.

Dr. Robert S. Lees was appointed Associate Professor of Metabolism and Human Nutrition and Director of the Clinical Research Center effective January 1, 1969. His field is concerned with the metabolism of the human plasma lipoproteins.

Dr. Padamakar P. Lele was given a joint appointment with the Department of Mechanical Engineering as Associate Professor of Experimental Medicine. Professor Lele is concerned with electrophysiology of the sensory nervous system with special reference to relief of pain and with the use of high-intensity ultrasound in the neural sciences. His office and laboratories are in the Department of Mechanical Engineering.

Dr. James K. Palmer has been appointed Associate Professor of Food Biochemistry effective July 1, 1969. He received his Ph.D. degree in biochemistry from Pennsylvania State University and until last year, when he came here as Visiting Associate Professor of Food Biochemistry, was principal research scientist at the Commonwealth Scientific and Industrial Research Organization Division of Food Preservation, North Ryde, N.S.W., Australia.

Dr. Robert B. Wilson, a veterinarian with a Ph.D. from Toronto, is coming to the Department in September, 1969, as Associate Professor of Nutritional Animal Pathology. He has had experience in the field of lipid metabolism in experimental animals which should complement the work of Professor Lees on man. Professor Wilson should thus provide excellent interaction in the human area and in the animal area with Professor Paul M. Newberne.

Dr. James F. Drummond is a young dentist who is receiving his Ph.D. in biochemistry at the University of St. Louis. He will be arriving in the early part of the coming academic year to be Assistant Professor of Nutritional Biochemistry and Metabolism and will also be Assistant Director of the Oral Science Training Grant.

Dr. William M. Rand is a young statistician who is receiving his doctorate in biostatistics from the University of California at Los Angeles. He will teach the two-term subject in biostatistics for the life sciences and be available for student and faculty consultation on statistical and computer problems. Professor Rand also has a Master's degree in statistics

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from Brandeis University and has served as the head of a computer group analyzing human shock responses. He has been appointed Assistant Professor of Biostatistics, effective September 1, 1969.

Dr. Dana E. Wilson, a physician at the Thorndike Memorial Laboratory, was appointed Assistant Professor of Metabolism and Human Nutrition, effective July 1, 1969. He will also serve as Assistant Director of the Clinical Research Center.

#### BUDGET AND FINANCES

Despite the reduced availability of National Institutes of Health funds, total financial support for the Department has remained constant because of increases in the assistance from foundations and industry.

NEVIN S. SCRIMSHAW

#### DEPARTMENT OF PHYSICS

During the summer of 1969 we expect to complete space on the first floor of Building 26 for use as a department reading room, which has been urgently needed for the past 15 years. We also expect to establish the medium-sized lecture room, 6-120, as a lecture demonstration room to aid in our new lecture subjects for freshmen and sophomores, and also to allow for demonstrations at any level of instruction. The large lecture room, 26-100, will be altered slightly to make demonstrations more palatable to large audiences.

During the last year degrees awarded by the Department include 94 Bachelor's, 18 Master's, and 48 doctorates.

#### UNDERGRADUATE PHYSICS

More and more students are taking the five-year Bachelor's-Master's program, so that it has become a major item of our undergraduate instruction. The new freshman physics, offered as 8.011 and 8.021, has been quite successful and will be continued next year. In addition, a special group, 8.01S, has been established, for the more mathematically inclined freshmen. The bulk of the freshman class will continue to be served by 8.01 and 8.02.

In furthering and supporting innovations in education introduced at M.I.T. generally, a number of students — perhaps as many as 150 — will be taking freshman physics in an entirely different method than in the past. One group, under Professor Earle L. Lomon and Professor Gian-Carlo Rota of the Department of Mathematics, will use the small seminar approach to both physics and mathematics, in which eight stu-

dents with one instructor will attempt to develop the whole of the subject, using the corridor laboratories and films as demonstration supplements. Another group, under Professor Jerrold R. Zacharias and Dr. Judah L. Schwartz, will use the laboratory approach for their entire freshman curriculum. The third group, under Professor George E. Valley, will attempt an intensified version of involvement of the student with modern science from the very beginning of the freshman year. These latter programs are all viewed as highly experimental and will be monitored very closely by the departments concerned.

For the last two years we have involved more students in active physics programs, both through the development of three family groups and through the one-to-one correspondence program. In the family group, students at all levels from freshmen through mature graduate students get together weekly with two faculty members to discuss current physics problems or classical problems from a current point of view. These discussions often lead to laboratory work for the undergraduates. In the one-to-one program, developed by David Newman, now a fifth-year student in the Department, a freshman or a sophomore is attached to a mature graduate student, helping in the graduate student's research and learning real physics in the process.

Following discussions with a number of students and faculty, we intend to allow a group of eight to ten sophomores complete freedom in their method of studying as far as their physics requirements are concerned. It is hoped that this additional freedom will encourage the students to pursue professional work at an earlier stage in their development and will give them a broader selection of formal subjects. This program has many foreseeable dangers for the naive student and will be the subject of prime departmental concern until it is proved out. In general, the Department is enthusiastic concerning the success of our innovations in the learning process.

#### RESEARCH

##### CENTER FOR THEORETICAL PHYSICS

The Center for Theoretical Physics has continued its participation in most of the important developments in elementary particle, nuclear, and astrophysics. We mention here only some of the more important achievements. In particle physics, the Center was fortunate to have Professor Gabriele Veneziano as a member; he recently proposed a successful model for the description of interactions between elementary particles. His presence at the Center stimulated a great deal of discussion and work. Besides Professor Veneziano, members of the Center, including Professors Sergio P. Fubini, Kerson Huang, Ira S. Gerstein, Vigdor L.

Teplitz, Steven Weinberg and Visiting Professor Kurt Gottfried have been developing important improvements and generalizations. In another area Professor Francis E. Low has developed a new integral equation to describe peripheral elementary particle reactions, which form a significant fraction of those observed in high-energy reactions. The properties of the solutions of the equation and their experimental significance are now being developed by Professors Low, Cecil E. Jones and Visiting Professor James E. Young. Professor Gottfried has studied the optics of the photon- $\rho$  meson system which has some unusual aspects because of the relatively weak interaction of photons with matter, the strong interaction of  $\rho$  mesons with matter and the ready convertibility of photons into  $\rho$ 's. A very important development has been the discovery and study of nonlinear realizations of chiral groups by Professor Weinberg. Professor Weinberg is completing a new book on the general theory of relativity. Because of its emphasis on the physics of the subject, this volume will have an important effect on that field, which has recently become more interesting experimentally.

In nuclear theory we mention the development by Professor Lomon of a theory of nuclear forces based on boson exchange. This theory permits the inclusion of recoil and relativistic effects for the first time in a systematic fashion. Professor Felix M. H. Villars has developed a fundamental theory for the rotational properties of nuclei. Until the present, such nuclei were described in semiphenomenological terms. Professor Herman Feshbach has developed a method for calculating and predicting low-lying states of nuclei; the method is rapid and does not require the use of computers for its elucidation. It promises to be of importance for the calculation not only of nuclear systematics but also for the determination of detailed nuclear properties. Professors Arthur K. Kerman and Carl M. Shakin's studies of isobar analog states, their width and their fine structure, are being incorporated in an extensive article for the *Review of Modern Physics* which will undoubtedly be the authoritative work in that field. Professor Kerman, with Professor William H. Bassichis, is also engaged in studying the existence of islands of stability for trans-uranic elements. The existence of such stable super-heavy elements ( $Z = 114$ ,  $N = 184$  is an example) would not only have a profound impact on our understanding of nuclear structure but also might possibly provide us with new technological tools.

In astrophysics Professors Philip Morrison and Leo Sartori have published their account of the light of a supernova outburst. There is good reason to expect that the spectra, light curves, and optical supernova intensity are for the first time explained by the curious retardation effects and the fluorescence which form the bases of this theory. Professor

Morrison also has developed a new understanding of the diffuse X-ray background observed in satellite experiments. It is possible to account quantitatively for the observed intensity and spectrum of isotropic X-rays between  $\frac{1}{2}$  keV and several MeV. As a consequence there is strong evidence for the open Friedmann cosmologies and for the supernova source of cosmic rays. Finally, we mention Professor Morrison's very interesting suggestion that a quasar is a giant pulsar.

Professor Morrison gave six Christmas lectures for a "juvenile auditory" of the Royal Institution of London. This was the 139th annual series and the first ever presented by a lecturer not a British subject. The series title was "Gulliver's Laws: The Physics of the Large and the Small."

#### EXPERIMENTAL NUCLEAR AND HIGH-ENERGY PHYSICS

In the area of radioactivity and heavy-ion research a main effort has been the broad and variegated program led by Professor Lee Grodzins. It encompasses work ranging from plans for a search for heavy elements in cosmic rays, to the study of superconductor properties, and the measurement of properties (moments and g-factors) of rotational and vibrational states of nuclei using several innovative techniques for embedding radioactive sources and ions in crystals and ferromagnetic media. Notable this past year was the continuation of the systematic measurement of the magnetic moments of  $2+$  nuclear excited states (of which about 50 have by now been measured) and the initiation of pilot balloon flight studies related to the proposed measurement of distribution of elements in cosmic rays.

The interest of physics staff in heavy ion research (notably the groups associated with Professors William W. Buechner, Harald A. Enge, and Grodzins) extends more broadly to heavy-ion induced reactions using accelerators elsewhere. M.I.T. work this past year has involved the Tandem accelerators at the Universities of Pennsylvania and Rochester, and plans are being proposed for the use of new equipment now under completion by the High Voltage Engineering Corporation at Burlington, Massachusetts.

Work in intermediate-energy nuclear physics, using electron beams, is being carried on at the National Bureau of Standards Linear Accelerator by the group working with Professors Walter C. Barber and William Bertozzi. Well-resolved data has been obtained on levels in several elements of importance. This work is being conducted both for its own value and because of the significance it has in preparation for the program of research planned for the 400-MeV LINAC (electron accelerator) being constructed by the Laboratory for Nuclear Science at Middleton.

Details of progress of the LINAC's construction are given in the progress report of the Laboratory for Nuclear Science.

In high-energy physics, groups working under Professors Martin Deutsch, Bernard T. Feld, Jerome I. Friedman, David H. Frisch, Robert I. Hulsizer, Henry W. Kendall, Louis S. Osborne, Irwin A. Pless, Lawrence Rosenson, and Samuel Ting have continued with active programs at a number of high-energy accelerators, including the Cambridge Electron Accelerator. Of note here have been: the preparation of experiments for use with the new electron-positron storage capability being built into the Cambridge Electron Accelerator; the analysis of bubble chamber data obtained from chambers at the Argonne National Laboratory and at the Stanford Linear Accelerator; a continuing and very significant study of the excited states of the proton by means of electron scattering at the Stanford Accelerator; elementary particle studies using spark chambers at the Brookhaven National Laboratory; and an extensive program at the German synchrotron in Hamburg (DESY) to examine the validity of quantum electrodynamics at small distances and the photo-production of  $\phi$ ,  $\rho$  and K mesons. Of special note this year also is the planning that has begun for work with the 200-BeV accelerator under construction at Batavia, Illinois. Several members of the physics faculty will participate this summer, as was done last year, in studies at Aspen, Colorado, directed toward the planning of research for that machine. Several tangible experiments are under consideration by M.I.T. staff for possible implementation by the time the machine reaches operation.

#### RADIOACTIVITY CENTER

In the Radioactivity Center, under the direction of Professor Robley D. Evans, research on many facets of pure and applied radioactivity continued vigorously, with increased funding from the U.S. Atomic Energy Commission (AEC). Measurements were completed on the total internal conversion coefficients for electric quadrupole transitions in six heavy nuclides from  $^{240}\text{Pu}$  down to  $^{224}\text{Ra}$ .

In the nuclear era which society is now entering, it is essential that radiation protection be sufficient but not superfluous. The present international Radiation Protection Guides for internal emitters such as plutonium and strontium-90 are based on a Radium Radiation Protection Standard determined by quantifying the effects of various amounts of radium in human beings, especially early radium chemists and radium dial painters of the 1920's. The present international Radium Radiation Protection Standard was based in 1941 on less than 30 radium cases who had been studied at the M.I.T. Radioactivity Center between 1934

and 1941, and served as the guideline for plutonium protective measures in the reactor and nuclear weapon developments of World War II.

A number of special techniques have been developed, including thick-source alpha spectroscopy, for quantifying the alpha-ray dose to microscopic regions of bone and adjacent tissue. The number of radium patients studied at the Radioactivity Center, with the medical collaboration of the M.I.T. Clinical Research Center and the M.I.T. Medical Department, has increased during the last year to more than six hundred. This permits a tentative statistical analysis of the response of human beings to graded dosages of skeletal alpha irradiation. One result of fundamental radiobiological significance is that the biological response of human beings to various doses of skeletal alpha irradiation is definitely non-linear, in contradiction to a hypothesis which is used widely in the field of radiation protection. This dose-versus-response relationship shows instead a "practical threshold" of radiation dose, below which human beings can be exposed over a period of several decades with negligible chance of radiation injury.

In the long-range future the importance to society of the distinction between a linear and a threshold model requires that the radium population under study be increased to include all available cases and that these individuals be studied throughout their full life span which, for some, will extend beyond the year 2000. The Division of Biology and Medicine of the AEC has made long-term arrangements for the continuation and completion of these basic radiation studies which will involve a gradual transition of this program to a new Center for Human Radiobiology in the Argonne National Laboratory.

A second matter of basic radiobiological significance is the study of the induction of lung cancer in American uranium miners as a consequence of inhaling alpha-ray-emitting decay products of radon in the mine atmosphere. Besides the epidemiological studies, the Radioactivity Center group has introduced significant engineering improvements in uranium mine ventilation practices and has developed a family of new alpha-radiation detection and monitoring instruments for use in the uranium mining industry.

#### ASTROPHYSICS

The astrophysics division of the Department of Physics continues to be active in a wide variety of fields of astrophysics, both theoretical and experimental. A new richness of the physical universe has been revealed through the discovery of new classes of objects by observations in the radio and X-ray regions of the electromagnetic spectrum. The recently discovered, and very intriguing, pulsating radio sources ("pulsars") have been studied by both the X-ray and radio astronomers in our De-

partment, and a successful rocket flight by Professor Hale V.D. Bradt's group revealed that the X-ray pulses from the Crab nebula are synchronous with the visible light pulses to a millisecond or better.

Significant advances were made this year by the group working with Professors Herbert S. Bridge, George W. Clark, Walter H. G. Lewin, and Bruno B. Rossi, through balloon and rocket experiments, in establishing the location and nature of X-ray sources. At higher energies (above 100 MeV) an important observation was the detection of gamma rays from the Milky Way containing a component of radiation that originates in extragalactic space. A major additional activity has been the analysis of plasma data from various satellites that have yielded significant results on the spatial and energy distribution of electrons in the magnetosphere.

Professor Icko Iben, in his continuing studies of stellar interiors, has shown that the failure to observe neutrinos from the sun does not yet require major revisions of element abundances in the sun. The uncertainties of reaction cross-sections and the neutron lifetime still allow solar models that have a "normal" helium abundance of the order of 25 per cent by weight.

Radio studies of interstellar hydroxyl, OH, by Professor Alan H. Barrett and his students have revealed a new class of interstellar maser, in which the radio radiation appears most strongly at 1612 MHz, a line frequency that ordinarily should be weak. The radiation appears to be associated with infrared objects that are presumably protostars, or stars in the very earliest stage of formation.

A new region of the electromagnetic spectrum has been opened by Professor Clark, in collaboration with Professor William L. Kraushaar of the University of Wisconsin and Professor Gordon P. Garmire of the California Institute of Technology. A satellite, carrying their directional gamma-ray detector, has shown that gamma rays of 100 MeV and higher energy came from the galaxy, exhibiting a strong concentration toward the galactic plane and especially toward the center of the galaxy. The intensity appears to be nearly an order of magnitude greater than was expected from best estimates of interstellar conditions.

Plasma experiments on the satellites OGO I and OGO III, flown by the M.I.T. solar plasma group, have given extensive data on the spatial and energy distribution of electrons in the earth's magnetosphere, the plasma bubble carried by the earth as it travels through the solar wind. Professor Vytenis M. Vasyliunas has shown that these data define a most interesting distribution of low-energy electrons, much more complex than expected from present theories. The most striking feature is on the dark side, where the low-energy electrons are distributed in a thin sheet



bounding the neutral sheet, which stretches far away from the earth's dark side, and the new data allow one to map the neutral sheet into the auroral zone.

#### LASERS

During the last year, the optical and infrared laser group has explored a variety of fundamental problems in modern precision spectroscopy and in the general area of interaction of coherent laser radiation with matter. These activities have covered a broad range of the spectrum, from the submillimeter and the far infrared to the short-wavelength ultraviolet. As in the past, emphasis has been placed on the development and application of new types of experimental techniques enabling improved accuracy in precision studies of atomic and molecular processes. The technique of absolute frequency measurements has been extended from the microwave range to the infrared portion of electromagnetic radiation; this has been made possible through developments of special rectifier and frequency mixer diodes and means of manipulating them in the infrared as lumped circuit elements, much the same as the radio frequency and microwave diodes; the technique is now being applied in precise definition of length and time standards and in a redetermination of the speed of light with improved accuracy. A variety of spectroscopic measurements has been explored, in which nonlinearities of atomic and molecular resonances are used to achieve significant narrowing of spectral line profiles, in some cases enabling orders of magnitude improvements in resolution and accuracy.

In a different area of investigation, novel aspects of propagation and transmission behavior of a short duration pulse of intense laser radiation through absorbing media are explored, emphasizing new features which arise from coherence properties of the applied radiation. Other research activities have included application of infrared lasers in the exploration of magneto-optical effects in solids, and studies of molecular energy transfer and vibrational relaxation in gaseous systems.

#### SOLID-STATE AND ATOMIC PHYSICS

Many developments and results of consequence have been obtained by our departmental staff in areas of solid-state and atomic physics in the past year. Specific mention of many of these is given in the reports of the central research laboratories such as the Francis Bitter National Magnet Laboratory and the Research Laboratory of Electronics. Additional activities which have been supported in the Center for Materials Science and Engineering include those of the theoretical groups under Professors George F. Koster, Peter D. DeCicco, and Marlan O. Scully,

and the experimental groups of Professors George B. Benedek, Thomas J. Greytak, and James D. Litster. Thus Professor Koster's group has investigated the band structure of gray tin and lithium through use of augmented plane wave methods and has studied inelastic collisions of electrons with atoms particularly in the case of argon atoms, for which cross sections to the first excited state were calculated. Professor Scully's group has continued to investigate the interaction of electromagnetic radiation with matter, particularly for cases of high peak power laser pulses, to understand better the collective aspects of an N atom (super-radiant) system as it interacts with the radiation field, and to pursue quantum statistical mechanics theory. The latter has included theoretical studies of the properties of superconducting tunnel junctions, evaporation from liquid helium II, the coherence properties of scattered light, the quantum theory of coherence, and the quantum theory of measurements. All of these theoretical studies have been correlated closely with experimental research of Professors John G. King, Ali Javan and Benedek.

In the laser light-scattering laboratory of Professor Benedek, accurate measurements of the change in shape of the enzyme lysozyme as it undergoes denaturation under the action of guanidine hydrochloride have been carried out. This measurement is performed by using the techniques of optical mixing spectroscopy to resolve the extraordinarily narrow line width of light scattered by solution of these molecules. The same technique has been used to measure the previously undetermined molecular weights of very large bacteriophages.

Other light scattering research by Professor Greytak has succeeded in detecting the spectrum of laser light scattered by rotons in liquid helium below the lambda point, and this permits accurate measurement of the energy, the density of states, and the lifetimes of the rotons. Professor Litster has made very precise measurements of the magnetic equation of state of the insulating ferromagnet  $\text{CrBr}_3$  in the immediate vicinity of its critical point and, together with Professor Peter Schofield, visiting from the Atomic Energy Research Establishment at Harwell, a mathematical transformation has been developed which reduces the equation of state to an extremely simple form.

Activities in the solid-state area have continued in the neutron diffraction laboratory of Professor Clifford G. Shull, where polarized neutron scattering studies have been used in studying the atomic magnetization distribution in magnetic materials and where the basic process of Bragg diffraction is being studied in perfect crystals. The latter has demonstrated the presence of a subinterference within Bragg reflected neutron beams, and this interference structure has been exploited in supplying

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novel information about neutron wave packets and in permitting very accurate determination of neutron scattering cross sections.

#### PERSONNEL

During the coming year, Professors David H. Frisch and Malcom W. P. Strandberg will be on sabbatical leave for the second term, and Marlan O. Scully will be on leave of absence for the entire year. We welcome as visitors Dr. Fortunato T. Arecchi, Professor of Quantum Optics at Milano University, who will be Visiting Professor during the first term, Dr. Eugene P. Gross of Brandeis University, Visiting Professor during the second term, and Dr. Gabriele Veneziano, Visiting Assistant Professor in the Center for Theoretical Physics.

Dr. Steven Weinberg, who has been Visiting Professor for the last two years, has accepted an appointment with us as Professor. Also joining us as Professors in the Department are Dr. Michel Baranger, formerly Professor of Physics at Carnegie-Mellon University, and Dr. Kenneth G. McCracken, of the University of Adelaide, Australia. Dr. McCracken will not assume his new duties until after the first of the year.

Other new faculty members in the Department will be Dr. Brian B. Schwartz, Associate Professor, formerly a Staff Member at the Francis Bitter National Magnet Laboratory, and Assistant Professors George F. Bertsch, Wit Busza, Roman W. Jackiw, Norman F. Kurnit, and H. Eugene Stanley. New Instructors will be Truman R. Brown, John E. Elias, E. Victor George, Charles T. Grant, Dae M. Kim, Margaret A. L. MacVicar and Michael R. Sogard.

During the last year a new type of academic position, Senior Research Scientist, has been created at the Institute. This position is considered much more suitable for long-term professional scientists than is that of D.S.R. staff member, which is more of a postdoctoral appointment. It carries many of the same privileges as faculty membership but is an automatically renewable three-year appointment instead of tenure. As of July, 1969, seven members of the Department will hold this appointment: Dr. Vera Kistiakowsky, Dr. Alan J. Lazarus, Dr. Charles P. Sargent, Dr. Judah M. Schwartz, Dr. Edwin F. Taylor, Dr. William F. Turchinetz, and William U. Walton.

The following faculty members received promotions as of July, 1969: To Professor: Thomas H. Dupree, (joint appointment with the Department of Nuclear Engineering), Samuel Ting. To Associate Professor: Thomas A. Belote, Ira S. Gerstein, Herbert S. Schnopper, Marlan O. Scully. To Assistant Professor: Saul A. Rappaport.

One faculty member in our Department, Professor Philip M. Morse, retired this year but will remain with us as Senior Lecturer. His many

contributions to national problems will be recorded elsewhere. Here we will mention only his impact on the affairs of the Department of Physics and its students. Coming to M.I.T. in 1931, he was already co-author of the first American book on quantum mechanics. Later and for many years Phil was graduate registration officer. He was usually the first M.I.T. faculty member a graduate student met; and it was a warm, personal introduction to M.I.T. as well as a significant, long-lasting interest in the student and his academic ambitions which Phil furnished. This carried over into concern for the teaching program of both the graduates and the undergraduates. He was responsive to individual needs and very often would give special unscheduled advanced subjects to a few students. In his research activities Phil's great contribution was to the interface between physics and engineering. Using the mathematical techniques and tools of modern physics, he revolutionized the science of acoustics, contributed much to electromagnetic theory, was a pioneer in operational research methods, and was one of the first to recognize the great importance of computer technology.

VICTOR F. WEISSKOPF

## PROVOST

**T**he past year was particularly challenging and interesting. On the one hand continuing efforts were needed to keep existing academic and research programs alive and vital in the face of severe economic difficulties and intense social unrest. At the same time, major efforts were required to bring into existence a variety of new interschool research and teaching activities designed to deal with the social problems of the times.

In last year's report, financial difficulties were predicted for many activities at the Institute because of expected reductions in the budgets of the National Science Foundation, the Atomic Energy Commission, and the National Aeronautics and Space Administration. The anticipated cutbacks did occur, and, in addition, several of the federal agencies who support academic research were required to operate under expenditure ceilings, which were in turn passed on to the universities. As a consequence research programs on the campus suffered many hardships, in the form of stretchouts, lack of funds for needed equipment, inadequate support for graduate students, and a shortage of money to sustain an appropriate level of activity during the summer months.

Fortunately a number of independent sources of research financing were available to help meet the most severe difficulties. The Sloan Basic Research Fund, the Godfrey L. Cabot Solar Energy Research Fund, and the National Institutes of Health (N.I.H.) Biomedical Sciences Support Grant were particularly helpful in mitigating the impact of federal cutbacks. This emergency help was not without its negative impact, however, for the primary purposes of these funds are to facilitate the startup of new research activities, to provide the funding needed to explore tentative new directions, and to provide for the unusual or emergency needs of ongoing activities. We must strive to build up these independent sources of re-

search financing, for it is likely that federal support will continue to fluctuate. It is also possible, in the near future, that support will become even less available in some fields of great interest to members of the faculty.

The most severe funding problems exist in those rapidly emerging research and teaching areas related to the vast social problems facing the nation where there has been no tradition of federal help. The problems here are newly recognized, at least by most of us, and large numbers of faculty members and students wish to devote their creative energy to understanding and helping to solve them. Here the federal government has been able to assist financially only very modestly until now, so that in spite of a general awareness of the needs, a great deal of political rhetoric, and determined faculty efforts to move into these socially desirable activities, our responses have been limited and slow. Among these problem areas where need and interest greatly exceed support are: urban studies, educational research, biomedical engineering and health care systems, policy studies, and the management and protection of the environment. Fortunately, a few of the foundations have recognized the difficulty and provided lifesaving assistance, particularly in the urban fields and the biomedical areas. We are especially grateful for the assistance we have received from the Ford Foundation, the Richard King Mellon Charitable Trusts, and the Commonwealth Fund. Major assistance from the IBM Corporation has also been of great importance in the startup of activities in the Urban Systems Laboratory and in educational research. The area of educational innovation has been given a dramatic impetus by funds made available by Dr. Edwin H. Land through a special trust he has created to support educational experimentation.

#### INTERDEPARTMENTAL ACTIVITIES IN URBAN STUDIES

The primary responsibilities for teaching and research in the urban field reside with the individual departments and schools, especially in the Departments of City and Regional Planning, Civil Engineering, Political Science, Architecture, and in the School of Management. The most challenging urban problems, however, are those which span several disciplines and require collaboration across departmental and school boundaries for effective investigation. Furthermore, students recognize the interdisciplinary character of the contemporary urban scene and increasingly want to have their formal study programs include courses in several departments. For these reasons, the Provost's Office has tried to facilitate collaboration and movement among departments and schools. Two specific mechanisms have been employed: the Urban Coordinating Group and the Urban Systems Laboratory.

## PROVOST

### URBAN COORDINATING GROUP

The Urban Coordinating Group (U.C.G.), in the second year of its operation, with the Provost as Chairman, had substantially the same membership and purposes as in 1967-68. It was created in that year to coordinate the activities of the various individuals, departments, and laboratories at the Institute oriented toward teaching, research, and direct participation in urban affairs and to stimulate those interdisciplinary activities which have as their objective the development of the Institute's ability to respond in a meaningful way to the complex problems of the urban area.

The most time-consuming activities during the year involved evolving teaching efforts at various levels. A *Curricula in Urban Studies at M.I.T.*, which served to bring together the variety of urban-oriented curricula for graduates and undergraduates in the Departments of Architecture, City and Regional Planning, Civil Engineering, Economics, Political Science, and Management, was prepared by Dr. Lucy Nedzel of the Provost's Office. In addition, special faculty advisers for these various groups were appointed. The *Curricula* was distributed in considerable volume to current and prospective students. The latter group was able to find out about the *Curricula* through a promotional poster which had been mailed to high schools and colleges throughout the country.

The *Curricula* has also served as a useful position paper for the Committee on an Urban Curriculum of which Dean Emeritus John E. Burchard is serving as chairman. The other members of this group are:

Professor Stanford O. Anderson  
Professor Richard L. deNeufville, Vice Chairman  
Professor Aaron Fleisher  
Professor Robert M. Fogelson  
Professor Earle L. Lomon  
Professor John R. Myer  
Professor Jerome Rothenberg  
Professor Leon S. White  
Professor David G. Wilson

It is the task of this committee, after examining the variety of teaching efforts in urban affairs, to suggest whether and in what ways to coordinate these efforts more closely. Moreover, the committee will concern itself with identifying major gaps in current teaching efforts. A report is anticipated from this committee in the fall.

In the spring, the U.C.G. sponsored the second all-M.I.T. Conference on Urban Affairs. The conference, of which Professor Robert C. Wood was Chairman, took place over a day and a half and focused on interdisciplinary research activities, reactions, and hopes for these activities

in the future. Faculty were involved heavily in the first segment, graduate students in the third, and outside experts in the second. The conference was a low-keyed success in that it provided an opportunity for exchange of ideas on the scope, substance, and method of urban research among faculty, students, and outside experts. However, the fact that it occurred after a week in which long student-faculty dialogues about the nature and essence of the Institute had taken place, meant of necessity that its impact was somewhat diminished.

In the concluding days of the academic year, members of the U.C.G. turned their attention to the critical questions of what the purposes of the group should be and what structure it should have to achieve these purposes. The group also considered how teaching, research, and direct participation in urban affairs ought to be organized and funded for the coming years. Answers to these critical questions should begin to emerge during 1969-70 and should have considerable impact on the Institute's capability in this important area of inquiry and concern. Frank S. Jones, Executive Director of the Urban Systems Laboratory, served as secretary for the Urban Coordinating Group and it was largely due to his efforts that the arrangement operated.

#### URBAN SYSTEMS LABORATORY

The Urban Systems Laboratory was created early in 1968, through a generous grant from the Ford Foundation, as one major element in strengthening M.I.T.'s capacities in the urban field. This reporting marks its first full academic year of life. Although a fuller accounting appears later in this report, it seems desirable here to place the Laboratory's particular thrust in the larger context of the Institute's urban effort in both its academic and extra-institutional dimensions.

Most heartening is the fact that the Laboratory has succeeded in operating along the lines originally laid down: It has been a primary instrument in crossing departmental boundaries; it has brought together faculty and graduate and undergraduate students from diversified disciplines; it has united these groups not only for meaningful studies within M.I.T. but has further linked them effectively, through action programs, with the outside community.

Though flexibility is the key to its entire functioning, the Urban Systems Laboratory operates within a defined structure. As opportunities appear, as priorities drift or shift with changing realities, as new techniques evolve, and as regroupings of people and rearrangements of facilities occur, the Laboratory modifies its structure. The current year has demonstrated the Laboratory's feasibility and its capability; the future



must see its continuing progress consolidated with effective solutions to fiscal and organizational challenges.

#### INNOVATION AND REFORM IN UNDERGRADUATE EDUCATION

The adoption by the Faculty four years ago of the principal recommendations of the Committee on Curriculum Content Planning signaled the beginning of a period of intense interest in innovation and reform in those portions of the undergraduate educational program which influence most or all undergraduates, particularly during their freshman year. This trend has continued at an increased pace during the past year and has spread to include upperclass subjects as well. In general, the undergraduate educational programs are moving away from the nearly monolithic first-year program of past years toward the accommodation of a rich variety of first-year programs which differ in content, style, and objective. Such diversity is valuable for two reasons. First, the young people who come to the Institute as undergraduates represent an increasingly broad spectrum of educational background and career objectives. Second, the range of educational programs offered by the departments is also broadening. While these upperclass programs are tied together by a strong commitment to the methods and strength of science-based education, they require increasing diversity in the preparation of undergraduates entering the various alternative courses.

The changes taking place in the first-year program reflect increasing flexibility in two independent dimensions. On the one hand, curricular alternatives differ in terms of content and objectives, that is, in terms of the assumptions they make about preparation and background, in terms of the directions they establish and the pace at which they move, and in terms of the goals or objectives toward which they build. On the other hand, these alternatives differ as well in terms of the relationships established between student and teacher and in terms of the learning styles that are encouraged. For example, in some subjects the emphasis is on the mastery of a body of knowledge, or on the personal development of a set of skills and techniques. In other subjects the emphasis is on independence and self-direction in the establishment of goals and pace, or on the development of modes of inquiry which are appropriate for new problem areas.

During the past year, the range of alternatives in the first-year core-subject area increased once again. There are now five alternatives in Humanities, three in Mathematics, three in Physics, and four in Chemistry. Within each subject area these alternatives differ in content, in scope, and in objectives, while remaining similar in style and mode of operation.

Several programs which primarily emphasize different educational

styles or modes of encounter have been developed during the past year and will be offered to freshmen on an experimental basis next year. The Experimental Study Group, a group composed of both students and faculty, has worked intensively over the past year to develop an integrated first-year program which places strong emphasis on student self-direction and autonomy and on student-faculty collaboration in the definition and achievement of educational goals. This group, under the general leadership of Professor George E. Valley Jr., will undertake an experiment along these lines with a small number of freshmen during the coming year. At the same time, a group in the Education Research Center, under the leadership of Professor Jerrold R. Zacharias, has developed an integrated first-year program which places strong emphasis on the laboratory as a vehicle for introducing students to a multidisciplinary approach to the study of science. This Unified Science Study Program will also be tried with a small number of freshmen in the coming year. Also next year a number of freshmen will study some or all of their core subjects in a seminar-tutorial format rather than in the usual lecture-recitation format. This experimental program, which is under the general direction of Professors Earle L. Lomon and Gian-Carlo Rota, is intended to be more amenable to needs of students for flexibility in pace, and is intended to encourage a more active involvement of both students and teachers in the learning process. We are also developing a program which will encourage the participation of undergraduates on a continuing basis in research activities, by making it possible for a student to receive academic credit for a planned program of activity with a professor and his research students. These programs, as well as that discussed in the following section, have been given a major impetus by the Land Education Development Fund.

#### **NEW EDUCATIONAL OPPORTUNITIES FOR DISADVANTAGED STUDENTS**

In the past, relatively few black Americans have come to the Institute; typically in recent years there have been two to five black students in each entering class. Many factors have been responsible for this situation. First, there have been so few black scientists and engineers that a typical black student is quite unlikely to view these professions as promising career routes. Second, for a typical black student, even if seriously interested in science or engineering, admission to M.I.T. as an expensive elite school was likely to appear almost impossible.

Actually, this could well have been the case in the past for many potentially good students, for there is a substantial difference between black high school students and others in terms of such traditional measures of scholastic achievement and promise as the College Entrance Examina-

tion Board tests. For example, the CEEB has reported that black high school seniors have a mean score on the Scholastic Aptitude Test that is about one and a half standard deviations below the national mean score, and that only one to two per cent have scores *above* the national mean. Admission to M.I.T. has traditionally been determined by an undifferentiated process which places strong emphasis on nationally-based test scores. The fraction of black high school seniors having test scores in the range characteristic of M.I.T. undergraduates is exceedingly small — probably less than a few tenths of a per cent. Consequently, very few black Americans have applied for admission to the Institute, and very few have been regarded as admissible.

During the past year, the M.I.T. Black Student Union prepared a set of proposals aimed at making the Institute more relevant to black people. These proposals focused on the aspects of recruitment, admissions and student aid policy, and academic program, which would make possible a substantial increase in the number of black students at the Institute. In order to implement these proposals, as well as to deal with other programs concerned with educational opportunities for disadvantaged young people, a joint student-faculty-administration group, The Task Force on Educational Opportunity, was formed.

There are several compelling reasons for undertaking intensive efforts to increase the number of black Americans who study at the Institute. First, the science-based education for leadership, which has long been our strength, is as relevant and as essential in the black community as it has proved to be for others in this society. Second, our commitment to areas of science and technology which bear on critical social problems, such as the broad area of urban affairs, requires that black Americans, who have a major stake in these concerns, participate fully in the development of solutions. Finally, we have a responsibility to contribute toward the ultimate resolution of the social crisis which divides this nation and imperils its future.

We have, therefore, undertaken to increase substantially the number of black students at M.I.T. by means of an intensive recruitment program and by assessing their qualifications for admission in ways that reflect their true potential, taking into account the probable consequences of economic deprivation, educational disadvantages, and socially-limited horizons. On this basis we have admitted 52 black students to the Class of 1973, entering in September, 1969. These students are uniformly characterized by outstanding secondary-school performance and by extraordinary personal qualifications, including strong motivation and interest in science-based education. Some 20 to 25 of these students have CEEB scores that fall outside the usual range characteristic of M.I.T.

freshmen. We believe that this gap can be closed by a combination of special educational efforts on our part and personal effort and determination on the part of these students, so that these young people may proceed through the Institute in the usual way, enrolling in the usual range of academic programs and meeting the usual standards of achievement and quality.

Toward this end, we have developed a special transitional summer program to help these students close whatever preparation gap may exist by sharpening those academic skills and techniques which are important in the first-year program. In addition, special counseling and tutoring resources will be available to these students during the next academic year.

As this program evolves to meet the need, the specifics are likely to change. Nevertheless, the commitment we have undertaken to expand educational opportunity at the Institute for disadvantaged Americans, including black students, clearly represents a relatively long-term program which will influence the shape of undergraduate education at the Institute in the foreseeable future.

**RINDGE TEACHING ASSISTANT PROGRAM  
INSTITUTE SEMINAR 211**

It seems appropriate, in view of the many student concerns which are currently apparent, to draw attention to student-initiated projects which speak to the needs of the inner city. These are activities undertaken by students reflecting their deeply held convictions that they must share their education with others less fortunate than they. No more eloquent testimony to the determination of students to undertake significant programs can be found than the impetus for one of M.I.T.'s most unique educational ventures, which enables M.I.T. students to play a significant teaching role in one of the Cambridge high schools, while receiving M.I.T. academic credit. That such a development occurred is evidence both of significant student activity and the Institute's willingness to sponsor such an activity outside the scope of conventional educational ventures.

In the winter of 1967-68, a small group of students, mostly seniors, advertised for a meeting of those undergraduates interested in starting a high school. Some 250 students showed up for the first meeting, indicating their interest in teaching or in some way making a contribution to high school youngsters in the Cambridge-Boston area. Subsequent meetings showed that interest was high, and the students received official approval to continue the plan. The result of their efforts was that by the spring of 1968 the students had negotiated not a high school but a

method by which M.I.T. students could teach in Rindge Technical School in Cambridge. Through the offices of the Headmaster, Robert R. Sweeney, and with support from M.I.T. faculty, arrangements were concluded to provide for 25 to 30 students to teach regularly in the high school in English, science, mathematics, and social studies. The program would include seminars at M.I.T. taught by regular M.I.T. faculty, earning 12 units of M.I.T. credit. Professor William T. Martin of Mathematics agreed to be interim head of a planning group consisting of students and faculty. The student who led this program was Richard P. Adelstein '68, and it was his imagination and drive which brought into the planning Professors Philip Morrison of Physics, Jerome Y. Lettvin of Electrical Engineering, and Dr. Louis Menand III of Upward Bound.

During the summer of 1968, Professor Alan J. Lazarus of Physics replaced Professor Martin as faculty director, and Danny Fingerman '69 replaced Adelstein as student director. Others added to the group during the summer and later in the year, were Professors Frank D. Zingrone and Peter Elbow of Humanities, and Professors Warren Ambrose, Arthur P. Mattuck, and Nesmità C. Ankeny of Mathematics. By early October, 25 student teachers were assigned classes at Rindge, and the seminars at M.I.T. were under way. In the spring term, 30 students were teaching regularly at Rindge. A steering committee, made up of the faculty members involved plus a student from each of the subject areas involved, met periodically throughout the year to consider the progress of the program and to devise effective ways by which the program could relate both to Rindge Technical School and to other M.I.T. educational efforts in the community.

The seminars at M.I.T. were centered on the four disciplines represented in the teaching at Rindge. The weekly sessions attempted to grapple with pedagogical issues facing the students, to provide support in subject matter for teaching, and to provide the students with a means of cross-exchange for their experiences. Out of these seminars and from the steering committee came tentative conclusions concerning the program's future. It was seen as necessary for the Institute to provide as much curricular backstopping for the students as possible, to develop greater communications with the regular teaching faculty at Rindge Technical School, and to provide more systematic analysis of educational theory and practice. By the end of the academic year, the steering committee was prepared to sponsor a curriculum study during the summer of 1969 and to revise the format of the weekly seminars. Discussions with the Rindge Headmaster revealed that he was anxious to continue the program. He has provided continuing and invaluable counsel throughout the entire program.

## PROVOST

I believe it important again to underscore the student involvement in initiating this venture and the continuing student responsibility for assistance in administering it. Close student-faculty involvement from the outset has demonstrated the strengths both have to bring to such a venture but particularly the serious insights students have about their own experiences in teaching and in working with younger and less advantaged students.

Inasmuch as M.I.T. offers no professional courses in education, such a joint academic venture as the Teaching Assistant Program provides unique opportunities for our students. It offers, as well, an additional avenue for the Institute to relate the varying student teaching experiences now going forth, including Upward Bound and other programs being planned in the spring of 1969 for implementation in the 1969-70 academic year. This particular student-initiated program is a remarkable demonstration of student initiative at its most creative and sophisticated level.

### UPWARD BOUND

The Upward Bound program, serving 70 boys from Cambridge and Boston, brought together M.I.T. faculty and students in an academic program which operated for seven weeks during the summer and for 25 Saturdays throughout the academic year. The 9th, 10th, and 11th graders participated in a program of academic offerings which included English, mathematics, physics, biology, and social studies. The program was taught by four M.I.T. staff members and high school teachers in the summer and by a similar group including Wellesley College faculty and undergraduates and M.I.T. undergraduates during the academic year. It focused on academic activities in a frankly pre-college orientation. During the summer the 11th grade students took the PSAT examination of the College Board and the SAT examination in the spring of their junior year. A start was made on college counseling for these young men with a considerable impetus provided by Peter H. Richardson and John A. Mims of the M.I.T. Admissions Office.

Since the students in the program all come from poverty areas in Cambridge, the program's staff spent a good deal of time working with the parents and neighborhood groups, in order to encourage the kind of support necessary for the boys to begin to live up to their academic potential. Parents' meetings, work with school counselors, and continual contact with neighborhood counseling personnel provided necessary communication. Boys who ran afoul of the law were represented in court by the Upward Bound staff working closely with the Harvard Law School Legal Volunteers. In each of the legal cases, Upward Bound staff were

successful in providing appropriate testimony and in assisting the boy in his efforts to straighten himself out.

During the year, two boys were accepted into the ABC program at Dartmouth College and spent the summer of 1968 at Dartmouth before going to independent schools in September. In the spring of 1969, four boys were accepted into the same program. A fifth boy was enrolled in a private school in Boston to provide a more helpful atmosphere in which to find his academic bearings.

Beginning in the fall, with support from the Office of the Provost and a later grant from the M.I.T. Community Service Fund, a number of Upward Bound boys were enrolled in a work study program at the Institute which involved their participation after school in laboratory activities supervised by faculty and graduate students. The boys worked in the aeronautics wind tunnel and in biology, psychology, and oceanography laboratories. Through the Education Research Center six boys assisted in the development of a mathematics curriculum for the ERC-sponsored Unified Science Study Program.

The close association with Wellesley College continued through a Saturday program during the academic year for the entire 11th grade group of boys. The program of English and math and workshops was taught by Wellesley faculty and students. The similar program at M.I.T. was taught by M.I.T. staff, high school teachers, and M.I.T. undergraduates. It was, however, due to the success of the Wellesley Saturday Program that Wellesley invited M.I.T. to use its campus for the 1969 summer program. Together with substantial financial support from Wellesley and from M.I.T., an \$80,000 grant for 1969-70 from the Office of Economic Opportunity permitted planning to proceed in the spring of 1969 for the summer program which was to be residential and, for the first time, co-educational.

The details for this operation were worked out by participation of Upward Bound students, parents, and the Upward Bound Public Advisory Committee, consisting of parents and members of the Cambridge Economic Opportunity Commission and the Harvard Graduate School of Education. At the time planning was proceeding for the new program, the Director of Upward Bound, Louis Menand III, was appointed Executive Officer of Political Science and Assistant to the Provost, creating a vacancy in the position of Director. The Institute is particularly fortunate in having John P. Terry as the new Director, beginning in June of 1969. Mr. Terry came from Union College where he had been financial aid and admissions officer and then director of the Union College Upward Bound program started in 1967. Mr. Terry's strong academic orientation and his deep interest in community participation augur

well for growth and continuation of the program. Upward Bound promises to remain an important avenue through which M.I.T. undergraduates can gain educational experience.

Upward Bound, as a pre-college academic and service program for the poverty community in Cambridge, can be seen as one method by which the Institute provides M.I.T. students with practical and systematic experience in teaching and in working with less advantaged young people. During 1968-69, the Director of the program offered a course in Politics of Urban Education which was heavily enrolled in by M.I.T. and Wellesley students working in Upward Bound. Some of the same students participated in the Rindge Teaching Assistant Program. Members of the M.I.T. Black Student Union worked in the program, and this participation was mutually supportive. Upward Bound staff participated in the work of the ad hoc Committee on Job Training and Education which concerned itself with recruitment of minority persons for laboratory technician positions at the Institute. In short, the Upward Bound program is a resource which can add to the educational enterprise at the same time it attempts to assist 70 young Cambridge students prepare for education beyond high school.

#### **WELLESLEY-M.I.T. UNDERGRADUATE EXCHANGE PROGRAM**

This was the first official year of this experimental five-year program. The program was announced by President Ruth M. Adams and President Howard W. Johnson on May 17, 1967, and there was a small exchange in 1967-68. In the first term of 1968-69, approximately 80 M.I.T. students took subjects in 18 Wellesley departments, and 95 Wellesley students took subjects in 13 M.I.T. departments. A shuttle bus service was set up and a meal exchange was arranged.

In the second term, approximately 100 M.I.T. students elected to take subjects in 21 Wellesley departments, with the largest concentrations in English, psychology, education, history, and sociology. During the same term, about half of the 13 M.I.T. subjects chosen by Wellesley cross-registrants were in the humanities, while a large number of Wellesley students chose subjects in political science, architecture, psychology, and electrical engineering (mostly computer subjects).

The students, on the whole, have done well in the subjects they selected and have accomplished this in spite of some problems in reconciling the different schedules of the two institutions and in allowing for the extra time needed for travel between the two schools. One M.I.T. student clearly stated some of his thoughts on the exchange:

. . . I think that it is enlightening to experience first hand the approach of another academic institution. Many people I know who are involved in the exchange have



fervent opinions on the way their "home" institution could be improved; some of these ideas have come from the exchange. . . . Wellesley's environment is physically quite different from M.I.T.'s, and I think the two complement each other well; one hears M.I.T. people complain frequently about the lack of trees and grass, and Wellesley girls complaining about being "out in the woods." Having an opportunity to spend time in both places offers one something better than a compromise; it offers some of each.

One faculty member expressed his reactions to the exchange as follows:

. . . Wellesley girls in my class . . . have raised the level of classroom performance, and they have stimulated our M.I.T. undergraduates. . . . The girls have been quite articulate, and this has made the boys also speak out more than they might otherwise have. The general result is a feeling that there is a more "meaningful audience" so that people try to perform at their very best at all times.

Another faculty member commented as follows on the Wellesley students in his class:

They are eager, work well with the M.I.T. students, and I find that in the work we are doing the cross-reference between the two institutions enlivens class discussion. The mix of men and women is wholly positive. . . . The M.I.T. students are fearlessly questioned by the Wellesley students about some of their generalizations, and the M.I.T. students respond well. The atmosphere generated by these exchanges is good.

A student-faculty committee oversees the program. The M.I.T. half of the Joint Committee for 1968-69 consisted of Dean Robert A. Alberty (co-chairman with Dean Phyllis J. Fleming of Wellesley), Professors Stanford O. Anderson, Richard M. Douglas, and Walter A. Rosenblith, Dr. Benson R. Snyder, Dean Emily L. Wick, and student members, Albert M. Harlow, Amy Shigemoto, and Alan S. Willsky.

#### **THE JOINT HARVARD-M.I.T. COMMITTEE ON ENGINEERING AND LIVING SYSTEMS**

This Committee, established in 1967 by President Nathan Pusey of Harvard and President Howard Johnson of M.I.T. has completed its work, filed a report with the two presidents, and suggested that it be discharged. The Committee was established to explore the possibilities of bringing together more effectively the resources of the two institutions in health-related fields and especially how to stimulate greater collaboration between engineers and physical scientists on the one hand and medical scientists on the other.

The Committee had as its basic mission the identification of opportunities for collaboration in basic and applied research, health-related education, and medical care. The Committee and its Subcommittees on Education, Research, and Medical Care have met regularly; approximately 50 faculty members from the two institutions have participated. Both institutions conducted, jointly, during the summer of 1968, a study for the National Academy of Engineering. The study was directed by

Professor Murray Eden of M.I.T. and Professor David D. Rutstein of the Harvard Medical School, who acted as the co-principal investigators. It examined specific opportunities for an effective interplay of the physical and engineering sciences, mathematics, methods of management and technology on the one hand and biology, medicine and health care systems on the other.

Sixteen separate task groups with approximately 150 staff members from the sponsoring institutions and the associated hospitals participated in the study, which also included a conference on the present and potential interactions between the universities and the industrial and medical communities in which more than 50 representatives from 30 industrial corporations participated.

At the same time a catalogue of more than 100 research projects having a substantial engineering component and involving M.I.T. faculty members was completed by the Subcommittee on Research as part of the National Academy of Engineering study.

The Committee recommended that detailed planning and design go forward next year for the collaborative programs in each of the several fields of interest. It recommended a study of the most appropriate institutional form for the new enterprise, together with an evaluation of the resources needed and a determination of their availability.

The Commonwealth Fund has provided a grant to support this effort, and Dr. Irving M. London, Professor of Biology at M.I.T. and Visiting Professor of Medicine at Harvard Medical School, has agreed to direct the program.

#### COLLABORATIVE PROGRAM IN RADIO ASTRONOMY

This is the fourth year of intensive planning for a large fully-steerable radio-radar telescope. M.I.T. faculty and Lincoln Laboratory staff, working with 12 other universities in a nonprofit organization, the Northeast Radio Observatory Corporation (NEROC), will complete engineering design studies of the telescope in December 1969.

These studies have established that, by enclosing a steerable antenna in the protective environment of a radome, an extremely high precision instrument with a very large collecting area can be built at a cost per square foot substantially below that of existing telescopes. The studies reported last year for this NEROC design envisioned a 440-foot diameter antenna with a surface precision (1/10 inch) sufficient for operation at wave-lengths as short as 5 cm. Further refinements of the design this year make possible a surface precision of 40 thousandths of an inch which makes possible efficient operation down to 2 cm. For a microwave antenna, a diameter of 440 feet provides a collecting area more than four

times that of any that now exists. The antenna itself would be sheltered from wind, snow, and severe temperature changes by the protective cover of an electromagnetically transparent space-frame radome. In this controlled environment, the four-acre parabolic surface can be maintained to the required precision more easily because deflections are systematic and predictable. Costs can be low because the protected environment permits lightweight construction and a simplified drive and control system.

Grants from the National Science Foundation (NSF) totaling \$1.7 million have supported the NEROC engineering studies, and a request to build a 440-foot diameter radio telescope, based on the resulting design, has been before NSF since last year. A parallel request for authorization to proceed with this radio telescope has been submitted to Congress this year through the Smithsonian Institution.

JEROME B. WIESNER

PAUL E. GRAY

### THE CENTER FOR ADVANCED VISUAL STUDIES

The year 1968-69 was the second year of the Center's existence. Activities initiated in the previous year began to develop in three interconnected areas. The first is that of *individual creative efforts*, the artist Fellows concentrating primarily on finding new technical means to express their personal aspirations. The second is the area of *cooperative ventures*, tasks of major dimensions calling for collaboration of the artists of the Center with scientists and engineers from the faculty and student body of the Institute. The third area involves *communicating ideas generated at the Center to the general public*, through publications, forums and symposia.

Of these various areas of activity, the most legible was that of individual artistic pursuits. The high quality of artistic achievement, as well as the impressive range of productivity, was to a large degree generated by the interactional, stimulating climate of the Center. The collaborative projects had less rewarding results but, nevertheless, made important strides. Lack of sponsorship, no budget for experimentation, as well as some unfortunate extraneous reasons, worked against the development of the most promising ventures. The Fellows' many publications, lectures and participation in symposia had a national impact.

Artist-Fellows Otto Piene, Vassilakis Takis, and Harold Towish continued their work at the Center this year, and Jack Burnham and Ted Kraynik joined us as new Fellows. During the academic year, there were

two changes in appointments to the Center. Mr. Takis, after completing his first year fellowship, decided, for personal reasons, to leave for Europe but offered to return to continue his work at the Center whenever a major task called for his talents. In March, 1969, Wen-Ying Tsai, a noted sculptor, was appointed for the fellowship vacated by Takis' departure.

In February, 1969, Stan VanDerBeek, whose recognition lies in the field of avant-gard filmmaking and experimentation in communication media, was appointed. He has a joint fellowship with the Center and WGBH and divides his time between the television station and the Center. In addition to his work with computer generated motion pictures, he is presently exploring the feasibility of large scale changeable murals based upon Xerox reproduction techniques.

Five research affiliates, Frank Carlton, Leslie Larkin, Frances Masland, Donald Pasquella, and Gary Rieveschl, were also active in the Center. Mrs. Larkin, with the collaboration of Mr. Pasquella and Miss Masland, continued her work on the film, "Nightscape of the City," which is close to completion. Gary Rieveschl, working on sculptures employing mechanical vibration and electric discharge phenomena, was involved in a variety of projects. He also collaborated with Kepes on a large scale kinetic light mural (8'x20') which was commissioned by the Boston University School of Medicine for one of their new buildings. He contributed a great deal toward developing and executing the design of the mural which is scheduled to be completed in August, 1969.

Foremost among the cooperative ventures was the development of a first year concern — the creation of a kinetic, luminous environmental spectacle for the Boston Harbor. The intention was to develop programmed luminous events to provide the urban environment with a focal hearth, a monumental gateway matched to the age of flight. The development of so complex a form could challenge not only the imaginative power of the artists but also the competence of structural, electronic, computer and systems engineers and city planners. Without sponsorship for this project, the work was able to assume only a theoretical dimension. Nevertheless, the Center hopes that some future support will enable it to realize its plans in concrete physical dimensions.

There were, however, some collaborative activities which were actually realized. The Center was invited in February by the Institute of Contemporary Art to present a three day light spectacle for the dedication of the new Boston City Hall. Ted Kraynik, Otto Piene, and Gary Rieveschl created a sequence of light events using a wide range of simple and complex lights. With the cooperation of over thirty participants, most of whom were M.I.T. students, Otto Piene organized two major outdoor

sculptural air experiments on the M.I.T. Athletic Field. Using in one event hot air-filled balloons and in the other helium-filled balloons, hundreds of feet in length, the artist and his collaborators produced a vital choreography of dancing sky sculptures.

The Fellows were involved in a number of events which presented the Center's ideas to the community. On January 15, Jack Burnham organized a forum in the Little Theatre of Kresge Auditorium on the theme "The Artist and the Scientific Community." The Director and the Fellows also participated in a major symposium presenting the ideas of the Center at the annual conference of the College Art Association.

Twenty-five graduate and undergraduate students from M.I.T. and Harvard University also worked at the Center during the year while taking Professor Kepes' course in Advanced Visual Design. Their work was related to the collaborative projects of the Fellows, primarily exploring environmental forms which combine audience participation with technological tools and natural phenomena. David Tulbert worked on a film investigating the role of mathematical measures in rhythmic light sequences. Miss Gretchen Dean, a special student, created a programmed light and sound performance shown in the M.I.T. Chapel. Her project, entitled "Immaterials," was cosponsored by the Protestant Ministry.

A number of magazines and newspapers reported on the Center's activities: *Product Engineering*, the *Harvard Art Review*, *Art Forum*, *Architectural and Engineering News*, *Spectrum*, *The Christian Science Monitor*, *The New York Times*, and the *Washington Post*. In addition, the CBS Twenty-first Century program on "The Art of Tomorrow" was devoted to the Center's activities.

Since the end of March, all efforts at the Center have been focused on preparing and designing an exhibition for the tenth Bienal de São Paulo (the major international art exhibition in the world). It was a singular honor for the Center to be asked by the Smithsonian Institution's National Collection of Fine Arts to represent the United States and take over the planning and execution of the United States section. Though there were major obstacles — a limited budget, limited time for preparation, and complex ideological and human problems — the Center accepted the challenge, for it offered an opportunity to express collectively the convictions of the artists working at the Center. Social and environmental interdependence, as fundamental to a livable contemporary life, is the core of this conviction. To symbolize this basic belief, our intention was to form, with a wide range of vital art works, an environmental community, which, like a synergetic system, can exist only through the interconnected workings of its members. Our aim was to realize an exhibition as a totality and not merely as an anthology of in-

dependent artistic statements, however rich they might be. Among the various art works prepared at the Center for the exhibition was a 15' by 80' electronically controlled light mural by Ted Kraynik, some large scale pneumatic structures by Otto Piene, a changing mural utilizing a creative application of some hitherto unexplored potentials of the Xerox technique by Stan VanDerBeek, and a 4' by 20' photoelastic walk realized by Gyorgy Kepes in collaboration with William Wainwright.

To make the exhibition as convincing and as comprehensive as was warranted by its role and theme, the Director invited twelve other artists from outside the Center to contribute to its common objective. To the great disappointment of the Center, more than one third of the participants withdrew from the exhibition (some of them in the last few days before the shipping date) for complex political reasons. They had chosen to boycott the exhibition as their way of protesting against the political situation in Brazil, which had brought serious hardship to fellow artists there.

The Center's present situation is essentially the same as the first year's, full of hopes and ambition but handicapped by a shortage of funds and a lack of equipment and materials for experimentation. At the same time, we are more convinced than ever of the contribution the Center could offer under more favorable circumstances. There are immense problems arising in our present complex social scene where the artist's contribution could be essential in finding resolutions. There is an increasing awareness of the need and the technological possibilities of an ecological climate which could offer the optimum quality of life under the present circumstances. Artists are in a strategic position to develop a civic awareness of our ecological problems. They could dramatize our ecological tragedies and celebrate the qualities of our social and environmental interdependence. Collaboration among artists, sociologists, urban planners and engineers who are concerned with our social and environmental difficulties could offer values that could not come from any other source. The Center's intention for the coming year is to utilize these potentials and develop closer contact with the School of Architecture and Planning and with the Joint Center for Urban Studies, interested industry, and civic groups with whom collaborative work could be achieved.

#### STAFF ACTIVITIES

Professor Gyorgy Kepes is a member of visiting committees and other advisory groups at the University of Hartford, Washington University at St. Louis, Harvard University, and the Museum of Fine Arts in Boston. He has published articles on Moholy-Nagy and numerous other topics. He gave lectures at the Ekistics Conference in Athens during the sum-

mer of 1968, as well as to the American Association for the Advancement of Science, the University of Cincinnati, Wheaton College, the College Art Association, and alumni groups. He has had shows in Montreal (a one-man show) and at the Smithsonian Institution, and he received an award from the California College of Art in San Francisco.

Jack Burnham has published widely during the past year, in the field of systems esthetics, in papers and lectures for the Guggenheim, various art magazines, and Stanford University, as well as a monograph for Penn State University.

Ted Kraynik, in addition to his work on large-scale light murals, has lectured on science technology and synergic art at the University of Miami and at Smith College.

Otto Piene has given lectures at Carnegie-Mellon University and Yale University and has designed material for television presentation, on NET in Boston and with Aldo Tambellini in Cologne, Germany. He has had one one-man show at the Howard Wise Gallery in New York, in April 1969, and another at Trumbull College, Yale University in May. His works include an Air Project as visiting professor at Karlsruhe Art Academy, in July 1968, "A Field of Hot Air Sculptures over Fire" at M.I.T. in January 1969, and sets for the ballet of Deutsche Oper am Rhein, Düsseldorf, in May 1969. In September, 1968, he served as consultant for light sculptures for the new capitol of Hawaii, and in March, 1969, two of his designs for the Senate and House light sculptures were accepted.

Vassilakis Takis had a major one-man show at the M.I.T. Hayden Gallery in November, 1968, and exhibited at the Howard Wise Gallery in March, 1969.

Harold Tovish had an exhibition at the Krannert Museum of Art at the University of Illinois and gave lectures at Tufts University, Maryland Institute of Art, and the New York State College of Ceramics.

Wen-Ying Tsai gave a lecture at New York University in December, 1968. He had a one-man show at the Howard Wise Gallery in June, 1968, and took part in several group exhibitions, including "Contemporary American Painting and Sculpture" at the Institute of Contemporary Arts, London, in August and September, 1968, and "The Machines" at the Museum of Modern Art, November through February, 1968-69.

Stan VanDerBeek has published several articles on computer graphics and has given lectures at 14 different museums and universities across the country and in Canada. He has taught film production at the University of Washington at Seattle and at the University of St. Thomas in Houston. He has been a judge at two film festivals during the year.

Gary Rieveschl, research affiliate with the Center, has collaborated with Otto Piene on four balloon and light sculpture presentations in the

#### PROVOST

Boston area and with Professor Kepes on the Boston University Light Wall. He has also contributed to light sculpture shows at Boston City Hall, Addison Gallery of American Art, Andover, Massachusetts, and the Brooklyn Museum.

#### VISITORS

Visitors to the Center during 1968-69 included Walter Gropius and Hubert H. Humphrey, as well as eminent architects, sculptors, designers, painters, and composers from Canada, England, Morocco, Israel, Italy, Holland, Australia, Iceland, and all parts of the United States.

GYORGY KEPES

#### CENTER FOR MATERIALS SCIENCE AND ENGINEERING

The Center for Materials Science and Engineering (C.M.S.E.) is in its fourth year of operation. Participation in the research programs includes major involvement by the Departments of Electrical Engineering, Metallurgy and Materials Science, and Physics, and important participation by the Departments of Chemistry, Chemical Engineering, Civil Engineering, and Mechanical Engineering.

There are about four hundred residents in C.M.S.E., including more than 50 faculty members, 70 academic and research staff, and more than 180 graduate students. Major support for this large effort comes from the Advanced Research Projects Agency (ARPA); the balance comes from a broad spectrum of contracts supported by numerous government agencies, industry and fellowship programs.

Central facilities, provided with modern, precision equipment and instrumentation to perform both service functions and research, continue to play a major role in promoting an interdisciplinary atmosphere. General services are provided by the central analytical laboratory, central machine shop, electronics instrument facility, central computation facility, C.M.S.E. library and reading room, and the central administrative office. Specialized research facilities include the microscopy and metallographic laboratory, the X-ray and electron optics facility, and X-ray and electron diffraction facility, and the gas analyzer mass spectrometer facility. Six laboratories for materials preparation and processing are extensively used: optical, magnetic and dielectric crystal growth; semiconductor crystal growth; metal crystal growth; semiconductor crystal processing; metal crystal processing; and ceramic materials processing.

#### RESEARCH ACTIVITIES

In view of the multiple nature of research support at C.M.S.E. and because of the dual citizenship of the faculty and staff, with ties both to



individual departments and to the Center, only a reasonable number of highlights of research attributable to ARPA support will be discussed. The reader is referred to *The Annual Report on Research in Materials at M.I.T.: 1968-69*, prepared by C.M.S.E., for complete coverage of all research in materials from all sources of support. Qualified applicants may request this report from the administrative office of the Center, Room 13-2145.

Professor David J. Epstein's group, studying photomagnetic effects and magnetic losses, has demonstrated that by illuminating a magnetically annealed sample of silicon doped YIG, one can shift the frequency at which microwave resonance occurs. The physical mechanism responsible for this effect is a change in the effective anisotropy field caused by the light-induced redistribution of electrons over one of the magnetic sublattices in YIG. The dynamics of this process, its effect on magnetic losses, the influence of light intensity and polarization, and related photoconductivity effects are among the questions currently being studied in detail. In studies of semiconducting ferro-electrics, ceramic samples of doped barium titanate have been prepared in which a  $10^{-3}$  increase is observed in resistivity in a temperature interval of  $10^{\circ}\text{C}$  centered on the Curie point. They do not find this positive-temperature-coefficient effect (PTC) in semiconducting single crystals, a fact which provides confirmation of a proposed theory which attributes PTC to depletion layers at the ceramic grain boundaries. An attempt will be made to fabricate a p-n junction in single-crystal barium titanate to create a well-defined "grain boundary," in which both the resistance-temperature behavior and the nonlinear volt-ampere characteristics of a PTC element can be studied in a simple configuration.

Professor Richard B. Adler and students are examining diffusion interactions in high-speed integrated circuit fabrication processes. The effect of a second diffusion in "enhancing" or "retarding" the diffusion of the first one in a variety of sequential multiple-diffusion processes for integrated-circuit planar transistor fabrication has been under study for some years, here and elsewhere. For the most common elements, boron and phosphorous in silicon, the effects are especially complicated. Evidence has been found that the "retardation" effect observed with heavily doped bases in pnp transistor-like structures does not develop during cooling. The proposed model for what does happen in those cases suggests that the more common "enhancement" effects observed in a number of different structures with less heavily doped bases, and in two different crystal orientations, are also not strongly associated with phenomena which occur primarily during cooling. Relieving the cooling-time constraint leaves open some reasonable choices in explaining the diverse

effects which have been observed, whereas attempting to adhere to this constraint makes the coherent modeling of all the processes extremely difficult.

Professor Robert H. Rediker's group is studying high-temperature semiconductors. Single crystals of stannic oxide of higher purity and with higher Hall mobility than any previously reported have been grown from the vapor phase. Undoped crystals of  $6 \times 10^5 \Omega\text{-cm}$  resistivity at  $300^\circ\text{K}$ , and antimony-doped n-type crystals with resistivity, carrier concentration, and mobility values of  $0.1 \Omega\text{-cm}$ ,  $4 \times 10^{17} \text{cm}^{-3}$ , and  $160 \text{cm}^2/\text{V-sec}$  at  $300^\circ\text{K}$  and of  $0.1 \Omega\text{-cm}$ ,  $6 \times 10^{18} \text{cm}^{-3}$ , and  $1200 \text{cm}^2/\text{V-sec}$  at  $77^\circ\text{K}$  have been grown, as have n-i junctions. Since  $\text{SnO}_2$  is physically and chemically stable at elevated temperatures and is a wide-bandgap semiconductor (bandgap of 3.7 eV), it is a strong candidate for semiconductor components which could operate at temperatures up to  $500^\circ\text{C}$ . While much more basic research on the conduction mechanism and technology are still required before practical tin oxide high-temperature components can be built, results thus far are extremely encouraging.

Professor Frederic R. Morgenthaler and his students are primarily concerned with microwave spin elastic wave interactions in ferromagnets and antiferromagnets. Interest in this field of what may be called "microwave magneto-ultrasonics" is warranted because of the fundamental information concerning spin-elastic wave interactions which can be obtained from magnetic and/or ultrasonic spectroscopy and because these interactions make possible novel microwave devices such as variable delay lines and pulse compression filters. They show that the frequency of a magneto-elastic wave propagating in a ferromagnet is altered by a suitable time variation of the bias magnetic field, and the character of the wave converted from spin wave-like to elastic wave-like (or vice versa) by suitable time and/or space variation of the bias field. The theory developed indicates, besides changes in frequency and in power flow, the temporal field gradient cause group velocity modulation and changes in the time duration of wave packets. In addition there is an exchange of momentum between the different branches of the dispersion relation; this exchange has been calculated in terms of critical field gradients for both shear and longitudinal waves propagating along certain crystallographic directions. Experiments which confirm the theoretical predictions on the propagation of magnetoelastic waves in time varying magnetic fields have been successfully carried out. Frequency shifts of spin waves as high as 1 GHz have been observed at L-band microwave frequencies, in axially magnetized rods of yttrium iron garnet. Experiments with magnetoelastic pulses were performed in cases where the signal is injected either as a phonon or as a magnon. The first demonstrates frequency conversion and group veloc-

ity modulation. The latter scheme is suitable to observe pulse compression and expansion due to frequency modulation and time changes of the group velocity. It has also been used to "trap" magneto-elastic pulses in the phonon state, by removal of the crossover point. Further, the coupling between antiferromagnetic and  $Mn^{55}$  nuclear resonances in  $RbMnF_3$  has been studied both theoretically and experimentally. A four sublattice theory predicts the NMR frequencies to good accuracy, for applied fields both greater and less than the spin-flop value. The temperature dependence of the crystal parameters has been included, and comparison has been made between theory and experiment in the temperature range where the parallel susceptibility is significant. Electron-nuclear double resonance experiments with  $RbMnF_3$  have been performed. Nuclear saturation was detected as a shift in the applied field AFMR. The measurements have yielded a value of 686.5 MHz for the unpulled hyperfine frequency and 55 msec for the longitudinal nuclear relaxation time.

Professor Mildred S. Dresselhaus and students have studied the graphite energy band structure. The success or failure of the one-electron treatment of the energy band structure of solids is thus being tested on the simplest and most fully understood materials through analysis of detailed experimental data in terms of such one-electron energy band models. The low quantum limit magnetoreflexion spectrum in graphite under high resolution conditions provides the kind of detailed experimental data that could test the limits of validity of such band models. The analysis, with graphite, so far has resulted in the identification of the sign of the carriers in the Brillouin zone, and in new information concerning the shape of the Fermi surface. This work has not only stimulated a number of new experiments on the electronic properties of graphite but has led to the development of a new theoretical technique for treating magnetic energy levels for coupled energy bands in solids.

Professor Alexander Smakula reports that his group's study of dielectric constant  $k'$  and dielectric loss  $k''$  of n-type, p-type and compensated silicon disclosed unexpected, sharp variations of  $k'$  and  $k''$  as a function of temperature. The observed discontinuities are characteristic of dopants, their concentration and ionization state. Similar effects have been observed in Ge, GaAs and CdS. The dielectric measurements furnish the intrinsic and extrinsic data of  $k'$  and  $k''$ , the influence of frequency and temperature, the influence of dopants (kind, concentration, ionization state and mutual interaction). These data indicate that dielectric measurements are a very powerful method for study of semiconductors.

Professor James D. Litster reports that magneto-optic techniques are being used to study several transparent ferromagnets in the critical region. This has proved to be a very precise way to determine the equation of

state in the critical region, and the results are applicable to fluids and gases as well as magnetic systems. The very large magnetic susceptibility in the critical region makes these materials attractive for high-sensitivity light modulators. In other studies, it was found that many materials exhibit an ordered liquid ("liquid crystalline") state which is potentially useful for optical display devices, temperature sensing, and study of surface properties. High-resolution studies of the spectrum of light scattered by liquid crystals are in progress. These will yield information on the time dependence of processes taking place in the liquid crystalline phase and during the transition to the mesomorphic phase.

Professors Benjamin L. Averbach and David J. Sellmyer report that Fermi surface measurements in beryllium and beryllium-copper alloys have been used to investigate the structure of beryllium. These results, along with measurements of elastic constants and Compton scattering, have indicated that the bonding along the C-axis has some covalent character, whereas the bonding in the basal plane is metallic. This anisotropy in bonding may be responsible for the easy cleavage of beryllium along the basal plane. Studies of electron transport and magnetic properties of transition metal-aluminum alloys have shown that the local environments of the magnetic atoms play an important role in the bulk magnetic properties of the material. When combined with short-range order information, these studies indicate the mechanism leading to magnetism, thus permitting control of magnetic properties by judicious alloying. Some of these alloys may have novel applications in thermo-electric heat pumping devices.

Professors Harry C. Gatos and August F. Witt, in applying the results of their investigations on the distribution of impurities in crystals, show that it is possible to obtain completely homogeneous indium antimonide single crystals for the first time. It is expected that the developed principles and techniques will be extended to other semiconductor single crystals (like silicon and germanium) where impurity heterogeneities are seriously hindering solid-state electronic device development. Further, a method has been developed for the preparation of vitreous materials which essentially overcomes the problems of chemical homogeneity, porosity (or inclusions), and lack of well-defined geometric shapes. It consists of the formation of the materials in a continuous laminated configuration. Although it has been applied only to arsenic selenide-antimony selenide system, it is essentially applicable to all vitreous materials.

Professor Robert M. Rose and students find very large increases in critical temperatures have been achieved in various types of thin films. The mechanism for such behavior is probably "phonon softening," which

raises the distinct possibility of structural instability in extreme cases. One such extreme case is the edges of thin films, where very high  $T_c$ 's may occur. They have demonstrated the occurrence of repeatable instabilities at the edges of granular Al films, and are presently studying this phenomenon by tunneling. The obvious goal of this work is to understand why and how high-temperature superconductivity of this sort occurs, but a very interesting by-product may be an understanding of structural changes at low temperatures.

Professor Roy Kaplow's students are studying the structure of  $\text{SiO}_2$ , which is currently not known, although it has found important uses as a masking material in electronics fabrication and appears to have some interesting optical transmission properties as well. They are determining the interatomic distribution function in powdered and thin-film specimens of this equi-atomic composition, amorphous material in order to describe the molecular configurations. Data has already been obtained with one X-ray wavelength, and additional experiments are being performed with a shorter wavelength in order to obtain improved resolution.

Professors Nicholas J. Grant and Regis M. Pelloux have studied the hot plasticity of various alloys in the cast form to establish the variables which control the deformability of these inhomogeneous, coarse structures. These studies have led to a process of highly efficient grain refinement by hot working commercial grade materials. Vastly improved plasticity is to be expected combined with large increases in mechanical properties.

Professor Carl W. Garland, using ultrasonic means to study potassium dihydrogen phosphate, has shown the effects of applied electric fields on a ferro-electric transition. Not only is the Curie point shifted, but the shear-wave velocity and attenuation are very sensitive to the field strength. Thus KDP might have the potential of acting as a tuneable delay line or an acoustic gate.

Professor David P. Shoemaker, by making use of the fact that low-energy electrons (of the order of 100 volts) penetrate only a few atomic layers near the surface, shows that the vibration amplitudes of atoms near the cleavage surface of a single crystal of zinc are larger than those of atoms in the bulk. An effective Debye temperature of  $127^\circ\text{K}$  was obtained with 92-volt electrons by analysis of the variation of the intensity of a diffracted beam with temperature; the bulk value is  $235^\circ\text{K}$ .

#### RESEARCH PLANNING

Coupling and cooperation between interested but scattered materials-oriented groups within the Institute has been a natural phenomenon, with important benefits for the participants, although communications

in an institution as large as M.I.T. is a considerable problem. Accordingly, a series of programs are planned which will encourage, accelerate, and improve the interdisciplinary approach to materials research. The first such effort, a Central Facility for Study of Surfaces and Interfaces, has been organized. It will have the latest, most advanced surface examining and analytical equipment available; the first items to be included are a LEED unit, scanning electron microscope, and a scanning ion spectrometer. Other facilities and instrumentation will be added as quickly as possible as the needs become apparent.

This facility will serve every department in the Schools of Science and Engineering, since every one of these departments now has research programs which are surface- or interface-related. The response among all departments has been enthusiastic. To serve as a focal point for exchange of information and ideas within M.I.T., and to provide external participation from among the elite in the field, C.M.S.E., through M.I.T. sponsorship, is supporting a two-week summer study program to examine in depth the latest theories, ideas, and techniques relating to surfaces and interfaces.

It is planned to approach other areas of broad interest in materials in a similar fashion. Areas of activity include materials processing, biomedical materials, and others.

During this past year greater emphasis has been placed on applying an important percentage of the research funds to "seed research" ideas. These are research proposals with an aspect of risk involved, in that the ideas are quite new, and usually not yet ready for formal funding from usual sources. Seven such programs have been selected for the next year. We foresee important developments from such research planning.

NICHOLAS J. GRANT

### **CENTER FOR SPACE RESEARCH**

The Center for Space Research has continued with an active program of general research in the space disciplines during the past year and has added further emphasis to some new studies and experiments in the general field of astrophysics. The overall program has included investigation of the properties of the interplanetary plasma, the solar corona, celestial gamma-ray and X-ray radiation and more recently, infrared radiation. There has been continued development and application of refined instrumentation, sensors, and experimental techniques necessary to the making of meaningful measurements involving these phenomena. Work carried out by the theoretical groups has included studies of the evolu-

tion of stars, globular clusters, and the general exterior ballistics of astronomical events of an explosive nature.

Through the medium of the NASA (National Aeronautics and Space Administration)-M.I.T. Sustaining University Grant (NGL 22-009-019), the Center has also administered a much broader program of space research on topics such as the societal implications of the national space program, space-related nutritional and biological studies, physical science studies concerned with the surface properties of planets, the characteristics of meteorites and tektites, and theoretical investigations of general galactic structures. In addition to these, there has been carried out under the same program a series of space-oriented engineering studies and experiments representative of the various engineering disciplines in fluid dynamics, materials, propulsion, communications, and electronics. Principal investigators representing some 13 departments of the Institute have participated in this latter phase of the Center's space research program.

The astrophysical research first described above has been carried out more or less within the Center's facilities and represents the combined output of three related groups: the cosmic ray group, under the direction of Institute Professor Bruno B. Rossi and Professors Herbert S. Bridge and George W. Clark of the Department of Physics, in collaboration with other faculty of that Department; the Laboratory for Space Experiments, under the direction of Professor John V. Harrington, Center director, and Richard H. Baker; and the astrophysics group, including Professors Philip Morrison, Icko Iben Jr., Leo Sartori, and William K. Rose, all of the Department of Physics.

In terms of overall research operations, these three groups have been conducting investigations under approximately 20 separate grants and contracts, the large majority of which are sponsored by the National Aeronautics and Space Administration, with a few grants from the National Science Foundation (NSF). Limited support for basic cosmic ray studies has also been provided through the Laboratory for Nuclear Science under an Atomic Energy Commission contract. Some exploratory study research in the Space Center has been provided for under Alfred P. Sloan Foundation basic research funds. The total research volume for all three groups is currently about \$2,400,000 per year. The personnel connected with this research effort includes 18 faculty, 3 instructors, 4 visiting scientists and engineers, 36 professional research staff, 60 research support personnel, 25 graduate students, and 15 undergraduates, a total of 161.

Based upon earlier indications as to the expected rate of growth of the Center, it had been anticipated that the overall level in the areas

enumerated would have reached about \$4 million per year as of July, 1969. However, the severe cutbacks in the Federal research budgets for fiscal years 1968, 1969, and 1970 have been responsible for a reduced rate of growth. Of even greater importance to the individual programs, these cutbacks have caused cancellations and delays in several scientific programs and thus have had a significant impact on the orderly and planned development of the overall program of research. Undesirable side effects from these interruptions unfortunately include a great deal of wasted effort by faculty and senior staff and lost opportunities for graduate student research and thesis activity.

While NASA has been, and presumably other Federal agencies are also, making sincere attempts to preserve some of these well-developed capabilities at M.I.T. by the substitution of new tasks, it is difficult, to say the least, in a field of research that is moving at such a rapid pace technologically, to maintain productive technical and scientific interest during such periods of indecisiveness.

The broader NASA-sponsored Sustaining University Grant program has also had its problems in that the total NASA funding for the research project phase of this program nationally has dropped from a high of about \$13 million in 1966 to \$5 million in 1969, with a corresponding reduction in the M.I.T. level from \$1 million to \$500,000. This reduction has put a severe strain on the Center's ability to keep the program multidisciplinary in nature while still maintaining a reasonable level of support for individual research efforts. At the peak of the M.I.T. funding in 1965-66, 35 space research projects in four schools and 14 separate departments of the Institute were being sponsored. During the year 1968-69 the number dropped to 23 active projects in four schools and 13 separate departments. These figures indicate that, while the distribution among disciplines has not declined materially to date, further reductions below the present level of funding would of necessity require a retreat from the broader coverage provided heretofore. During this period of declining funds, additional critical reviews have been made by the Center and its advisory committees to insure that maximum benefits were obtained from the Sustaining University Grant support. To this end, greater weight has been given to support of space-related research of an innovative and exploratory nature and particularly to such proposals received from junior faculty. At the same time, encouragement and assistance have been offered to those supervisors who have carried their research through the developmental stages, to seek direct funding assistance from appropriate agency sources. The Center has been moderately successful in this latter purpose, judging from the fact that ten to twelve ongoing research pro-



grams, with a combined annual volume of well over \$1 million, have evolved in this manner.

In retrospect, there are strong convictions on the part of those closely associated with the Sustaining University Grant program that, used wisely, the flexible nature of these funds supplies a powerful tool for the promotion and development of new research ideas and concepts. It has, therefore, been gratifying to see the responsible attention that NASA has devoted to urging Congress to keep the present Sustaining University Grant program, so that it remains a significant part of the NASA budget during a period of overriding national priorities and competition for Federal research funds.

Highlighting important new scientific discoveries and developments of the Center's research during the past year presents a difficult choice. The few research results cited in the following paragraphs are a small but representative sample.

In the area of experimental astrophysics there have been two major discoveries. First, the existence of primary cosmic gamma rays was firmly established by an experiment flown on OSO-3 (the Third Orbiting Solar Observatory). This experiment represents the successful culmination of one of M.I.T.'s first experimental programs in space science, started in 1958 by Professor William Kraushaar in collaboration with Professors Gordon Garmire and Clark. The initial experiment was flown on Explorer 11 in 1963 but did not yield conclusive results. Since that time two additional experiments were attempted but did not yield results, because one of the satellites did not operate properly, and one failed to orbit.

Thus there is a special satisfaction that the OSO-3 experiment launched in 1967 has worked perfectly and has shown unequivocally that a detectable intensity of high-energy gamma radiation reaches the earth from outer space. In addition to detecting gamma rays, the experiment has shown that the sky is not uniformly bright in gamma rays; rather, the intensity is concentrated in the plane of the Galaxy, and at a maximum toward its center. The theoretical implications of this remarkable result are just starting to be explored.

Second, rocket- and balloon-borne X-ray experiments have given new results on the positions, energy spectra, time variability, and angular size of celestial X-ray sources. Certainly the most exciting discovery in this field is that made jointly by an M.I.T. group under Professor Hale V. Bradt and optical astronomers at the McDonald Observatory and at Mt. Palomar. The X-ray measurements made with a rocket-borne detector show the existence of a strong pulsed X-ray signal from the pulsar NP 0532 (located in the Crab nebula), which has the same period and phase as the optical signal measured nearly simultaneously by the ground-based

telescopes. A similar X-ray observation was made a month earlier by a group of experimenters at the Naval Research Laboratory, but without the coordinated optical observations.

During the past few years plasma experiments flown by the M.I.T. group on OGO-1 and OGO-3 (Orbiting Geophysical Observatory) have returned the first definitive data concerning the distribution of low-energy electrons in the magnetosphere over a wide range of radial distance. These results have been analyzed in detail by Professor Vytenis M. Vasyliunas, who has shown that the spatial distribution of electrons is much more complex than that predicted by any of the present theories of the magnetosphere. While it is difficult to summarize the results briefly and at the same time accurately, one can say (somewhat loosely, at least) that the electron fluxes in the sunlit side of the magnetosphere show large dawn-to-dusk asymmetries and large variations with radial distance; in the night side intense electron fluxes are confined to a sharply bounded sheet-like region that extends to great distances away from the earth and also reaches down to the earth's atmosphere at high latitudes, forming a narrow zone that has been shown to coincide with the region of occurrence of the aurora. These experimental results have had a major impact on recent theoretical work which attempts to place our understanding of the magnetosphere on a sound quantitative basis.

The spatial distribution of electron fluxes in the magnetosphere, described above, represents an average behavior over a time scale of months. Large variations in intensity from this average occur on a time scale of hours or days and are probably related to changes in the solar wind and/or geomagnetic activity. In addition, smaller variations occur on a shorter time scale. These complex effects are not understood and their explanation will require a great deal of additional observational and theoretical work.

A planetary geophysics research group under the direction of Professor Thomas B. McCord, engaged in studies of the surface properties and atmospheres of planets, provides still another recent and welcome addition to the space scientists sharing in the facilities of the Center for Space Research building. Professor McCord is a member of the faculty of the Department of Earth and Planetary Sciences.

Activity in the life sciences in the Center building has expanded, with the addition of several research staff and graduate students engaged in experimental investigations of information transfer in prebiological environments. This research is under the direction of Professor Alexander Rich of the Department of Biology. In addition, the research of Professor Richard J. Wurtman and his associates, of the Department of Nutrition and Food Science, has been expanded by the conversion of additional

laboratory space to carry on research already in process and such additional topics to give a total program of experimental studies for: (a) the determination of which portions of the visual spectrum are able to synchronize the daily rhythm in body temperature in rats, and the amount of light intensity needed for each color; (b) determination of the effects of different types of generally used white light sources on growth and sexual maturation in rats; (c) analysis of the mechanism responsible for daily rhythm in amino acid metabolism; and (d) analysis of the mechanisms responsible for daily rhythm in the synthesis and release of brain neurotransmitters.

The research space assigned to the Man-Vehicle Control Laboratory for experiments and studies concerning the application of control theory to problems of man-machine interactions, human physiological subsystems, and the definition of new problem areas in biotechnological research, on the ground floor level of the Center building, has been temporarily expanded to provide additional room for graduate students and visiting staff. This extra space had been planned originally for mechanical and shop support activity, the immediate need for which has been deferred because of cutbacks in other aspects of the space program. This research activity is under the direction of Professors Laurence R. Young, Yao T. Li, and Jacob L. Meiry, all of the Department of Aeronautics and Astronautics.

Thus, in the second year of its availability, the Center for Space Research building has become just about fully occupied, although some minor shifting and settling in of the various research groups has continued to take place. Some further reassignment of working spaces is anticipated as the research of the Center continues to evolve to meet the new goals of the national space program and the responses related thereto by the M.I.T. academic community.

JOHN V. HARRINGTON

### **EDUCATION RESEARCH CENTER**

"The time is ripe for M.I.T. to make dramatic changes in teaching and learning, perhaps the boldest and most far-reaching since its founding in 1861 as a new institution innovative in spirit and method. Improved student preparation and motivation, experience in a variety of curriculum reforms, the stock of new ideas gained in educational experiments, the increasing application of technology to education, and growing insights into the environment of learning now offer an historic opportunity to achieve solid institution-wide changes and improvements in the learning process." These words, which open a recent Education Research Center

brochure, describe the developing position of the Center as a resource of the Institute for its own educational reform and as a center for such reform on a national scale. The brochure goes on to discuss the concentration of resources required for effective innovation. "Innovation in education demands many diverse skills and facilities and a level of human effort and sophistication that cannot be part-time. For example, to provide computer-animated film loops in quantum physics for a large audience requires effective mastery of computation, display, programming, photography, a working knowledge of psychology, pedagogy, editing, production, publication, distribution, teacher indoctrination, along with an appreciation of physical principles deepened and purified by repeated inspiration, coding, failure, and argumentation. Individual academic departments will always play a fundamental role in both curriculum development and experimentation. But a truly professional innovative effort requires a greater concentration of resources than is ordinarily available through the departments. The required concentration has many aspects:

1. Facilities for laboratory development, film making, and computer teaching;
2. Advice, criticism, evaluation by professional human sciences staff;
3. Knowledge of currently available options and alternative methods for learning;
4. Experience with available technologies and facilities for their further development;
5. Provision of a meeting-ground for interdepartmental cooperation on new courses and materials;
6. Funding for experiments too expensive or too wide in scope for single departments.

The Education Research Center seeks to multiply the effect of these separate strengths by locating them in one organization."

#### UNIFIED SCIENCE STUDY PROGRAM

The most ambitious new project undertaken by the Center during the past year is the Unified Science Study Program. This multidisciplinary undergraduate program is designed to provide the scientific foundations of a broad spectrum of professions and vocations for students of widely different backgrounds and career aspirations. The student has available a variety of open-ended projects for investigations, and he is assisted in choosing among those that appeal to him. Around these he develops a course of study. The student is encouraged to follow his interest in the chosen project across disciplinary lines and is provided with assistance as required from faculty and staff advisors, written guides and study units, laboratory and computer facilities. As an integral requirement for success

in his experimental work, the student acquires the basic tools of science — mathematics, precise verbal expression, fundamental laws of physics — as the need for them becomes apparent to him and to his faculty guide.

In the fall of 1969, more than 40 freshmen will begin their college careers with full-time involvement in the Unified Science Study Program. Plans call for the program to expand to 140 students in four years and for parallel efforts elsewhere in the nation.

#### SELF-PACED STUDY

Three other projects were initiated this year. The first is a trial of a self-paced study method for taking subjects. The student works at his own pace with new forms of self-study materials. Mastery of each topic is the single criterion of progress to the next topic. Undergraduate tutors provide individual help when needed and grade the achievement tests for each topic on the spot. A self-paced subject in relativity and electromagnetism was given successfully in the spring of 1969. Additional subjects in first- and second-year physics are in preparation for the fall and spring terms.

#### COLLOQUIUM

A second new undertaking is the establishment of a weekly Education Research Center Colloquium. This usually embodies a report on a specific educational project within or outside of the Institute, followed by general discussion involving students, faculty, and staff. Colloquium topics in 1968-69 included: Concentrated Study; Educational Implications of the Sakharov Paper; Health in Vietnam and in Urban America; Producing More Black Doctors; On Meritocracy: A Troubled Inquiry; and Schools for Human Beings. Some of the colloquia are of such general interest that they are being published under the series title *Occasional Papers of the Education Research Center*. Requests have been filled for eight hundred copies of the first issue, Concentrated Study. Other issues are in the process of preparation.

#### A SMALL TIME-SHARED COMPUTER SYSTEM

The last new project is the development of a small time-shared computer system for student use. By adding a magnetic disk memory unit to our small computer (PDP-7), currently used for computer-generated movies, we will be able to service ten terminals simultaneously with the BASIC computer language. Students in the Unified Science Study Program will presumably make frequent use of the facility. The self-paced study in mechanics and quantum physics will use computers to assist in the self-study of motion and the solutions of quantum equations. As the demand for this facility increases, other M.I.T. computers may be adapted for time-shared use by students.

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Ongoing projects of the Center — those started in previous years — have matured sufficiently that an adequate report on each is not feasible in this brief document. We list them here, with a sentence or two, indicating their general characteristics.

**PHYSICS, A NEW INTRODUCTORY COURSE**

This is the original project of the Center. It includes texts, corridor experiments, exercises and solutions, filmed demonstrations and lecturettes, and documentation experiments. Several additional texts are in preparation for publication. A corridor laboratory is open daily for student manipulation of demonstration experiments, and a description of a demonstration laboratory has been published by the Center.

**THE COMPUTER AS A TUTOR**

The M.I.T. TEACH system, a self-contained subject in computer programming operated on the M.I.T. time-sharing system, has been used on a trial basis for three terms with students taking subjects 17.733 and 6.471.

**HUMAN EFFECTS OF THE CURRICULUM**

A book on the completed student adaptation studies is in the final stages of preparation. Cooperation is in progress with the Unified Science Study Program on projects that integrate the social sciences (law, anthropology, sociology, psychology) with other disciplines. Several new studies are under way: on the student use of formal and informal counseling resources at M.I.T., on the social structure of the psychiatric service itself, on the college mental health services in the United States, on the effects of social process on the educational effectiveness of an electrical engineering subject, and on the social processes involved in the architectural planning of educational facilities at the Institute.

The following is a list of other M.I.T. educational innovations and experiments with which the Education Research Center is or has been involved.

Project Laboratories  
Family Plan Laboratories and Seminars  
Concentrated Study  
Undergraduate Seminars

JERROLD R. ZACHARIAS

**INFORMATION PROCESSING SERVICES**

The Institute's organization for managing its information processing services was strengthened this year by the formation of two committees to assist the Provost and the Director of Information Processing Services.

The Information Processing Board, appointed by the President, is chaired by the Provost. Its membership includes the academic Deans, the Comptroller, the Vice President — Organization Systems, the Director of Information Processing Services, two major laboratory heads who have special interest in computing, the Director of Project MAC, and the Director of the Urban Systems Laboratory. The function of the Board is to advise the Provost in policy matters concerning the Institute's computer facilities and programs.

The Director of Information Processing Services is advised by the Information Processing Advisory Committee, which represents the community of users of computation services. IPAC, appointed and chaired by the Provost, meets frequently and constitutes an important channel of communication between the various sectors of the user community.

#### BUILDING DEDICATION

A major event during the year was the dedication on November 11, 1968, of the Information Processing Center building. President Howard W. Johnson presided at this dedication ceremony, and the principal speaker was Thomas J. Watson Jr., Chairman of the International Business Machines Corporation. Mr. Richard G. Mills, Director of Information Processing Services, responded to Mr. Watson's dedication address and conducted a tour of the new building. A booklet distributed to guests at the dedication ceremony included a note about the Information Processing Center at M.I.T. which said in part:

Information processing now touches all aspects of life at the Institute: teaching, research, and administration. Drawing upon experience with digital computers, students, faculty, and members of the research and administrative staffs seek continually to develop and exploit computer capabilities in all three areas.

Student involvement, of course, is of special interest, and both undergraduate and graduate students are intimately involved in much of this activity. A large majority of students begin to use the computer early in their programs of study, and many continue to do so on into graduate work. Rich opportunities exist at M.I.T. within several departments for students to pursue programs oriented toward the computer sciences.

The Information Processing Center now serves M.I.T. as the large and versatile central component of a developing, campus-wide computer network whose goal is to meet the teaching, research, and administrative needs for information processing of all members of the Institute community. The Center offers its users a broadening spectrum of information processing services, including standard batch processing, remote-job-entry batch processing, on-line file manipulation, and general-purpose, interactive time sharing. Facilities already housed in the new building include an extensive IBM System/360 complex comprising a Model 65-40 Attached Support Processor System and a Model 67.

Also available is a specially modified IBM 7094 installation, which has been providing general-purpose time sharing to the campus and the New England colleges since mid-1963. The operating system software for this facility is the M.I.T. Compatible Time Sharing System (CTSS), developed in the Center by Professor Fernando J. Corbató and his staff.

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**TECHNICAL PROGRESS**

In terms of technical progress, a steady improvement in the coherence of the Institute's widely-distributed information processing facilities continues to take place. One of the two specially-modified 7094 computers that provided the campus with CTSS service was removed as the need for this type of service diminished with the arrival of newer equipment. Some of the Institute's time sharing users are served by the IBM System/360, Model 67 experimental system operated by the Center. Near the end of the year, others were beginning to use, on a developmental basis, the Multics system, which operates on the GE 645 computer and which the Center will offer to the general campus community early in the coming year.

The job-stream processing capabilities at the Information Processing Center, still exploiting a System/360, Model 65-40 Attached Support Processor System continues to improve in service capability. Using this system, with its various remote access capabilities, the Center is able to offer computer service with processing "turn-around" times that equal or better those available at comparable installations elsewhere.

The past year has demonstrated that the organization and reorientation of the Institute's information processing facilities has led to vastly improved computer capabilities for the campus and a substantially enhanced degree of coordination among the facilities providing these capabilities. A major part of the effort in the coming year will focus on supporting the faculty in its efforts to develop computer-based tools for innovative improvements in teaching.

RICHARD G. MILLS

**LABORATORY FOR NUCLEAR SCIENCE**

Work in L.N.S. continued this year across a broad front of activities in nuclear physics. In addition to an extensive and outstanding theoretical program, L.N.S.-related physics faculty and research staff carried on an experimental investigation of radiations originating in space, with observations of significance on the location and nature of X-ray and gamma-ray resources both within and outside our galaxy. Experimental research in radioactivity and heavy-ion research involved novel and powerful techniques for the elucidation of nuclear and solid-state properties of matter. A number of experiments were conducted at off-campus M.I.T. accelerators, from the study of low- and intermediate-energy nuclear phenomena using ion- and electron-induced reactions, to a wide spectrum of high-energy experiments carried on by means of bubble chamber, spark chamber and counter techniques at the Cambridge Electron Ac-



celerator, the Brookhaven and Argonne National Laboratories, the Stanford Linear Accelerator Laboratory, and, abroad, at the German Electron Synchrotron in Hamburg. Brief outlines of these projects, with names of the faculty involved, have been included in the report of the Department of Physics. Of note concerning future high-energy research is the participation of L.N.S. faculty and staff in studies at Aspen, Colorado, related to forthcoming research with the 200-BeV accelerator under construction at Batavia, Illinois. Several L.N.S. experiments are already under consideration for proposed implementation at that machine. More detailed reference to the work of the Laboratory is given in our yearly progress report: *Massachusetts Institute of Technology, Laboratory for Nuclear Science Physics Progress Report, M.I.T. -2098 - 540*.

While the research undertaken has been valuable and productive, the breadth and scope of all activities have been severely affected by the continuing drought in governmental support of fundamental physics. In particular, the support of new research and new personnel (even new graduate students), and the acquisition and timely development of new techniques and equipment have been restricted and carried through on a basis assuring greatest priority to ongoing, educationally oriented physics. We are making our plans with the expectation that this situation will continue for at least several years to come. A typical case has been that of the Laboratory's new 400-MeV linear electron accelerator, now under construction. The original funding for this machine, while adequate for the construction of the accelerator, is sufficient for target room and experimental facilities suited to carrying through only part of the exploration possible with this machine. As a result, priority has been assigned primarily to the development of a unique electron scattering spectrometer and to equipment for electron scattering research. The building for housing the accelerator and spectrometer is at present almost completed, and parts of it are already occupied. Assembly of components of the accelerator proper is expected to begin by late 1969 or early 1970, with partially accelerated beam in hand by late 1970. Assuming the acquisition of funds as requested for completion of the accelerator and for operation and development of research equipment, expected completion date for the machine and commencement of the electron scattering research program is late 1971.

Including work in cosmic rays, high-energy, medium-energy, low-energy, and theoretical nuclear physics, the Laboratory's physics research program last year involved the support of 65 physics faculty members, 105 doctoral students and approximately 40 undergraduates. Other Laboratory personnel involved in L.N.S. physics programs, on either a full or part-time basis, totaled approximately 330 people, including doctoral re-

search personnel, and technical and administrative support personnel. Costs for research operations and equipment in physics during the year totaled approximately \$5,400,000. A total of 29 Ph.D. degrees, 9 Master's degrees, and 25 Bachelor's degrees were completed during this period by students engaged in thesis research in physics within the Laboratory.

PETER T. DEMOS

### PROJECT MAC

Project MAC is an interdepartmental research laboratory for computer science and engineering. The research program of Project MAC is focused upon the new field of "interactive" computing, in which men and computers work together in close partnership in solving problems or making decisions. Some of the research is aimed at making it possible for men and computers to work together more effectively. Some of it takes advantage of interactive computing to facilitate the solution of basic problems in computer science or to develop new applications. Almost all of it, however, deals with men and computers, hence the acronym "MAC."\*

During the last year, Project MAC has accomplished several research objectives, and it has gone through part of a major transition. Inasmuch as a brief account of the transition will set the stage for a discussion of the research results, let us begin with that account.

\*There are other expansions of "MAC." Those we use most often are "multiple-access computers" and "machine-aided cognition."

### THE COURSE OF PROJECT MAC

In order to bring about a partnership between men and computers, one must make it both possible and economically practicable for men and computers to work together directly and effectively. The first major undertaking of Project MAC, beginning in 1963 and building on early work of the M.I.T. Computation Center, was to create a computer system with which many people could work simultaneously and conveniently. The result was the first general purpose multi-access computer system, the Compatible Time-Sharing System (CTSS).\* By 1965, CTSS was the focus of a significant part of the intellectual effort of about 200 research people at M.I.T. and quite a few at other universities. It was obvious that interactive computing opened new horizons. The present computer "time-sharing" industry, with its 150 to 200 service companies, is one of them. CTSS made it evident that a multi-access computer could provide the com-

\*Actually, two CTSS's were built. One was operated by Project MAC, the other by the Computation Center.

munication as well as the information storage and processing facilities required for the emergence of a new kind of intellectual community. Partly by having them and partly by lacking them, CTSS made it possible to see what characteristics and features a "community" multi-access system should possess.

The effect of CTSS upon Project MAC was threefold. The quick success, together with the flood of ideas of how to build a far better system, led to the determination to create a truly comprehensive community computer system, and, with the General Electric Company and the Bell Telephone Laboratories, Project MAC initiated a major effort toward that goal. Not all the computer scientists and engineers who contributed to the development of CTSS wanted to participate in the development of the more advanced system; many turned to research in other aspects of computer science and engineering. At the same time, CTSS tended to bring its community of substantive users, people interested in using interactive computing to facilitate research in their various fields, into Project MAC. Thus Project MAC came to have three main parts: (1) the computer system research group, developing the new multi-access computer system, (2) several smaller research programs in computer science and engineering, and (3) a large number of users of CTSS.

During 1967 and 1968, as the use of CTSS turned from a research experience into an operational routine, and as the development of the new multi-access system required an increasing fraction of the available funds, the third part dwindled. This past year, the CTSS operated by Project MAC was transferred to the Information Processing Center (formerly Computation Center), and Project MAC became a two-part laboratory. That was the first part of the transition.

The second part of the transition began on the first of January. The new multi-access system called the Multiplexed Information and Computing Service (Multics), had proven to be much more complex and difficult than anticipated, and its development had proceeded at just half the scheduled speed until the beginning of the new year. Then everything began to go well, the schedule quit slipping, and now the heart of Multics beats, the Multics Operating System operates.

The Multics that now "runs" is a bare-bones system, but an advanced one. The computer system research group is confident that it will be opened for general use on October 1, 1969, which will begin the third part of the transition. The main system research effort will turn from the operating system to the comprehensive library of procedures and data required to convert such a "system" into a "service," to make it effectively and conveniently useful to others than computer buffs. This service-build-ing effort will lead, we believe, to a realization of our dream of an "on-line"

intellectual community. But it will not bring the whole community into Project MAC — only the service builders. Operating responsibility for Multics will be transferred to the Information Processing Center.

#### CHARACTERISTICS AND FEATURES OF MULTICS

Inasmuch as the demonstration of the Multics Operating System was one of the main accomplishments of the past year, it is an appropriate time to explain the basis for the claim that Multics provides a new and unique facility for a true on-line community of users, a foundation for unprecedented teamwork in many kinds of undertaking that are based upon information. There are two main areas in which Multics represents a major advance.\*

First, Multics introduces a great simplification into the individual user's concept of the computer system. Heretofore, he had not only to remember the names of his programs and sets of data but also to keep in mind their sizes and, if large, squeeze them (all together or in subsets) into the computer's memory, which was pictured as a single series of little bins, each capable of holding one "word" of procedure or data. Using Multics, he thinks only in terms of the names; the operating system brings into memory those procedures and data required at each moment and does not waste expensive memory space (which can be put to good purpose by other users) on a user's inactive information. Programming within the context of Multics, the user has available to him the equivalent of millions of pieces of writing paper, each just as long as he needs it to be, but he need not remember how long, or where he put the pieces; he just names them and remembers the names. (If he forgets the names, Multics will of course provide a listing.) Nor does the user have to think about the configuration of the "hardware" computer. It may change basically, in number of processing units or in number of memory blocks, through failure of subsystems or through augmentation, but the only way that affects the user is to slow down or speed up the service. His working image of the configuration of the computer system remains the same: a "space" occupied by the names of procedures and data.

Second, Multics greatly facilitates cooperation among its users. It makes it easy for them to work in pairs or groups, using shared as well as individual programs and data sets and communicating with one another through their consoles as well as face-to-face or by telephone. To use another person's procedure or data, one has only to get his permission. One does not have to borrow a copy either overtly or within the system;

\*In the first of these areas, a few other systems, developed since the design of Multics was published, are comparable to Multics. In the second, to the best of our knowledge, Multics is unique.

two or more people can use the same "copy" of a procedure or of a set of data at the same time. Multics keeps one of them (and his programs) from changing it while the other (another) is in the process of "reading" it. Without permission of the owner, access to files is barred. The owner can extend permission to any individual or established group to use one of his files in any one of several ways: "read and change," "read only," "execute only," and "use only through a privileged program." The Multics file system provides the basis for free, voluntary cooperation and also the basis for entrepreneurial cooperation for a fee. Multics will keep records of the use of certain programs and data and send bills on behalf of the owner.

Professor Fernando J. Corbató, leader of the computer system research group, has a list of 30 characteristics and features, of which the foregoing are a few, which define Multics. They are set forth in the *Annual Report of Project MAC* for 1968-1969. It will not be long, now, until we see whether they will make the expected difference, whether they will greatly facilitate the individual's use of his own information and, at the same time, turn the computer into a communication network.

#### KNOWLEDGE AND HEURISTICS IN THE COMPUTER

Computers are so fast and accurate in their execution of procedures that they proved themselves very useful long before any computer was programmed to do anything that seemed at all intelligent. Indeed, to combine the computer's speed and accuracy in applying defined procedures to specified data with man's ability to formulate and evaluate is the essential aim of man-computer interaction. But communication between men and ordinary computer systems is so poor as to frustrate any attempt at teamwork. There can be little man-computer partnership if the computer knows practically nothing and has to be told at every stage precisely what to do and in detail how to do it.

A large and important part of the work of Project MAC is devoted, therefore, to learning how to "educate" the computer to be a better partner. It does no good simply to fill the computer's memories and stores with facts; the uneducated computer can remember but not use them. It does little good to fill the memories and stores with procedures; the uneducated computer has to be told exactly when and to what data to apply each one. The problem is, essentially, to understand the process of being intelligent and to program at least some of that process into the computer. It is clear that the process involves knowledge, which can be defined roughly as facts structured into a model that can be "run" or be interpreted by the processor, and heuristics, which can be defined roughly as guidelines to solution or discovery.

In Project MAC, during the last year, several accomplishments were made in the education of computers. In most instances, the computer system was the Incompatible Time-Sharing System (ITS), a system somewhat smaller than CTSS and Multics and specialized in quite different ways. You have to be a computer buff to use ITS, but, if you are, you like it so much that you do nothing to make it easy for nonbuffs to understand. As a result of the educational accomplishments, ITS can, among other things, now:

1. Solve calculus "word problems" of the type, "A ladder 20.0 feet long leans against a house. Find the rate at which the top of the ladder is moving if its foot is 12.0 feet from the house and moving away from the house at the rate of 2.0 feet per second." (E. Charniak)
2. Look (through its television-camera "eye") at a haphazard pile of toy blocks on the floor, analyze the scene into individual blocks (A. Guzman; B. K. P. Horn), pick them up one-by-one (with its mechanical arm and hand), and stack them up to make a tower.
3. Play Class C chess instead of Class D chess, as last year. (R. Greenblatt)
4. Solve symbolic (nonnumeric) integration problems, now even including problems involving logarithms and exponentials, such as the Gaussian ("error") function. (J. Moses)

The systems of programs which do the foregoing things, as well as others now operating, have some knowledge and some heuristic capability, but not much. They are successful only in quite special and restricted contexts. A large group, led by Professors Marvin L. Minsky and Seymour A. Papert, is working intensively to advance the understanding of such problems.

#### MAN-COMPUTER INTERACTION

Next to the stupidity of ordinary computer systems, the main barrier to effective and convenient communication between men and computers has been the computer "console." In practical fact, the console used in 98 per cent of all on-line man-computer communication these last few years has been merely an electric typewriter with additional electro-mechanical parts to send codes to and receive codes from a computer. Such typewriters are narrow bottlenecks. Obviously they had to give way to, or at least be supplemented by, graphic displays and nonkeyboard computer-input devices such as pencils and microphones.

The past year saw a marked advance in the commercial supply of ultratypewriter equipment for man-computer interaction. The Advanced Remote Display Station (ARDS), developed by the Electronic Systems Laboratory in conjunction with Project MAC, led an important part of

the advance. Its storage cathode-ray screen provides a nonflickering image of fairly good resolution and the capacity to display a standard page of typescript (unfortunately at somewhat reduced size). Most importantly, it can display graphs, diagrams, and maps, and it presents information very much faster than a typewriter.

Perceiving the importance of improved man-computer interaction techniques to the future of interactive information processing, Project MAC recently formed new research groups in computer graphics and dynamic modeling. As Multics moves from its developmental to its operational phase, increasing effort will be devoted to understanding and development of those areas.

#### COMPUTER LANGUAGE

The intrinsic "language" in terms of which a computer carries out its internal processes is hardly a language in the everyday sense; it is just a repertoire of primitive operations upon information in its memory and upon its own configuration. Great difficulties arose when men tried to communicate with the computer in its own "machine language." One of the main practical advances of the early years of computing was the development of "higher level" languages for use in preparing programs: FORTRAN, ALGOL, and so on. Then, when such languages were in widespread use, people began to subject them to linguistic analysis and to try to understand them theoretically. That effort led to a clearer understanding of natural languages as well as computer programming languages. It is a continuing study, but a part of it recently reached a culmination.

Much of the effort of the computer linguistics group of Project MAC, led by Professor John M. Wozencraft, had focused on working out a systematic analysis and exposition of the basic concepts of computer programming languages on the basis of a method called the lambda calculus. That effort was completed at the end of 1968. The exposition is presented in the class notes of Computer Linguistics, 6.231, and in several publications. The end of 1968 was thus the end of an era, and Professor Wozencraft took leave of absence to serve as associate head of a division of the Lincoln Laboratory. The group, now under the leadership of Professor Robert M. Graham, is attacking new computer language problems: languages for programming operating systems (Professor Graham), languages that can be readily extended by the individual programmer or programming team to meet special requirements (Professor Arthur Evans Jr.), and a new way of formalizing computer languages and formulating and proving theorems about them (Professor John J. Donovan).

At the same time, it is becoming increasingly clear that there is more to computer language than just language for programming. As the library of programs grows, the ratio of program preparation to program use de-

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creases, and the languages through which people interact with programs ("interaction languages") become more important. In a part of this new area, the area of data description language, Project MAC and the Special Interest Committee on File Description and Translation of the Association for Computing Machinery together recently initiated a weekly seminar.

### OTHER RESEARCH AREAS

Project MAC is active in other research areas, also, and made significant advances in many of them during the past year. Professors Joseph Weizenbaum and Robert R. Fenichel completed the first version of their computer program, TEACH, which teaches computer programming, and "proved" it on an introductory class.\* Professors Donovan and Malcolm M. Jones and their students developed an interactive simulation programming language SIMPL. Professor G. Anthony Gorry Jr. programmed an interactive system to facilitate diagnosis of certain diseases from clinical test data. Wendell T. Beyer found a way to reduce very greatly the amount of computation required in certain kinds of geometrical information processing. He found, for example, that through use of a parallel computer paradigm, the number of computational steps required to determine whether or not two figures, represented in a grid, are connected, can be made proportional to the number of intervals in one dimension of the grid rather than to that number squared. Harriet J. Fell worked out a way of dealing mathematically with topological problems that arise in discrete (gridlike) approximations to continuous spaces. In mathematical terms, she showed that the Hausdorff topology is the intersection of all possible grid topologies. It is not possible to do justice to them in a brief review, however, we mention several, not touched upon here, in a section about Project MAC in the report of the Department of Electrical Engineering.

Let us conclude the discussion of Project MAC's research, therefore, with a brief word about computer networks. This is, in our view, a new field of very great potential. Project MAC has initiated a new research group to work on computer-network problems and techniques. We are looking forward to participation in the experimental ARPA (Advanced Research Projects Agency) network, which will link multi-access computers in several universities. Abhay K. Bhushan has already published two papers in the new field and is planning doctoral research in it.

### ADMINISTRATION OF PROJECT MAC

Project MAC has a simple structure consisting of approximately 12 research groups, two computer installations, a document room, a publica-

\*This work was joint with the Education Research Center.



tions office, and a headquarters. It has a director, two assistant directors, and an administrative assistant to the director, who is the cement that holds the project together. Since Professor Robert M. Fano retired from the directorship at the end of the summer of 1968, Professor Joseph C. R. Licklider has been Director of Project MAC. Professor Jones and Mr. David Burmaster (*vide infra*) are the assistant directors. Miss Dorothea Scanlon is the administrative assistant to the director. In addition to conducting and publishing research, Project MAC conducts seminars and participates in educational undertakings. This past year, there were, in addition to the standard Project MAC colloquia, seminars in theory of computation and theory of automata and one (mentioned earlier and only recently started) on data description languages. Project MAC initiated two "project laboratories" (laboratories conducted on a research-project basis which yield regular academic credits), one in software systems and one, in connection with the Education Research Center and the Lincoln Laboratory, in computer graphics.

At the beginning of the summer of 1969, David Burmaster was appointed assistant director of Project MAC for student activities and business manager. As an M.I.T. student, Burmaster was an effective activist for student involvement in research and student access to computers. With a few colleagues, he conducted the campaign that led to the formation and funding of the M.I.T. Student Information Processing Board and, *inter alia*, to the initiation of the Computer Graphics Projects Laboratory. Under his direction, Project MAC is now dedicating itself to a major increase in student (including undergraduate student) participation. The computer field is a "natural" for young people. They not only learn to understand computer systems faster and better than their elders, but they are able to undertake significant original research.

Although its terms of reference encouraged diversified support, Project MAC was funded for the first five years of its existence exclusively by the Information Processing Techniques Branch of ARPA. This last year, while the Information Processing Techniques Branch of ARPA continued its major support at the established level, small or medium-sized additional research programs were undertaken under the support of NASA (Extensible Languages, Professor Evans, and a Laboratory for Research in Perception, Professor Marvin L. Minsky), the National Library of Medicine (Features and Costs of Multi-Access Computer Services, Professors Licklider and Corbató), the Office of Naval Research (Interactive Problem Solving and Decision Making, Professor Jones), and the Behavioral Sciences Branch of ARPA (Dynamic Modeling, Professor Licklider).

Project MAC contributed significantly to the planning and establishment of a new research project, the Cambridge Project, for computer analysis

and modeling in the behavioral sciences. The Cambridge Project has been funded by the Behavioral Sciences Branch of ARPA through the Defense Supply Service of the Army. The Cambridge Project will improve and specialize in interactive computer methods for use in behavioral-science research.

JOSEPH C. R. LICKLIDER

### RESEARCH LABORATORY OF ELECTRONICS

This interdepartmental laboratory provides facilities for academic research covering a large range of topics, most of which fall into one of three broad categories: general physics, plasma dynamics, and communication sciences. During the past year, 111 faculty members, 280 graduate students, and 78 undergraduates from a dozen academic departments participated in the program.

Research during the past year has resulted in the publication of 76 journal articles and three technical reports. In addition, the research provided the basis for 33 doctoral, 15 Engineer, 46 Master's and 41 Bachelor's theses. The total number of degrees based on theses supported by the Laboratory since it was founded now stands at 2,718, of which 622 were doctoral, 114 were Engineer, 904 were Master's and 1,078 were Bachelor's.

Major support for the research is provided by the Joint Services Electronics Program of the Army, Navy and Air Force as well as the Atomic Energy Commission, the National Science Foundation, the National Institutes of Health, and the National Aeronautics and Space Administration.

The current reduction of Federal expenditures for basic research has resulted in the termination of several contracts or grants and funding decreases of 5 to 15 per cent on those that have been renewed. In the face of rising costs and shrinking funds, it has been necessary to curtail some of our research activities and reduce the level of effort of others. Money obtained from the Sloan Fund for Basic Research has been most helpful as a partial offset for the prevailing conditions.

The following sections summarize the research activities of the past year.

#### GENERAL PHYSICS

The research in general physics includes a variety of activities, many of which are based on atomic resonance phenomena. The experimental techniques required to observe these basic properties of matter and to

exploit them in engineering applications span most of the electromagnetic spectrum from radio wavelengths to X rays. Other experimental requirements include the use of extremely high-frequency vibrational waves, the use of liquid helium temperatures, and extensive use of computers.

Professor John G. King and his students in the molecular beams group have continued atomic beam studies of liquid helium, some of which are directed toward understanding the process of evaporation and the nature of the liquid surface, while others exploit these processes as a sensitive means of studying some of the bulk properties. A potential outgrowth of these experiments is a molecular microscope, in which surface phenomena are investigated by studying the spatial variations in the evaporation or scattering of neutral molecules, eventually with high resolution and magnification. Such a device should yield valuable information concerning the weak forces important to chemical and biological phenomena.

The microwave spectroscopy group, supervised by Professors Malcolm W. P. Strandberg and Robert L. Kyhl, has made measurements of the noise figure of thin film superconducting bolometers evaporated on solid sapphire substrates. These measurements indicate an excess noise figure of about 15 decibels above the theoretical limit set by thermodynamic fluctuation theory. The mechanism of noise generation is not known, but the noise is quenched by a perpendicular magnetic field of a few Gauss.

The work on atomic resonance and scattering, under the direction of Professor Daniel Kleppner, has included a new experiment to compare the magnetic moment of the electron in hydrogen and in deuterium. The precision should be sufficiently high to reveal theoretically predicted effects which are presently too small to observe. The determination of the magnetic moment of the proton is essentially completed. Work is proceeding on a new type of superconducting detector which is intended to serve as a hydrogen atom counter, and which may have important applications as an infrared detector. Dr. Maung T. Myint has obtained encouraging first results.

A considerable amount of new information on alkali-alkali interactions has been obtained during the year by Dr. David E. Pritchard. The interactions are determined by the technique of atomic spin exchange scattering. Potentials in both the singlet state and the chemically unbound triplet state have been determined. Work is proceeding to extend the technique to other systems.

The radio astronomy group, under the supervision of Professors Alan H. Barrett, Bernard F. Burke, David H. Staelin and Richard M. Price, has actively pursued several lines of investigation.

Professor Barrett and his graduate students have discovered spectral

radio emission from hydroxyl (OH) radicals that originates from infrared stars. They are currently surveying about a hundred such stars to correlate the radio emission with other properties of the stars. Approximately 12 per cent of the infrared stars show OH emission.

Professor Barrett and his students are also observing the radio emission by water (H<sub>2</sub>O) molecules from selected regions of the Galaxy. Some of the sources of H<sub>2</sub>O emission correlate with OH emission sources, but complete correlation is lacking.

Professor Staelin has been designated as the principal investigator of a microwave experiment selected for inclusion in the payload of a future Nimbus meteorological satellite. The experiment is designed to yield the temperature profile and water vapor content of the atmosphere. Professor Barrett has been designated a co-investigator on this experiment.

Professor Burke and his students, and their collaborators at other observatories, have completed a survey of approximately two hundred ionized hydrogen regions in the Galaxy, allowing dynamical studies of the large-scale spiral structure through the ionized component of interstellar gas. The northern part of the survey was carried out with the 140-foot telescope of the National Radio Astronomy Observatory in Green Bank, West Virginia, and the Southern Hemisphere was studied with the 210-foot telescope of the Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.) Radiophysics in Sydney, Australia.

A large antenna array has been constructed for use in the study of pulsating radio sources (pulsars). The work was done under the supervision of Professors Burke and Price with substantial participation by undergraduate students.

The solid-state microwave electronics group, under the direction of Professor Robert P. Rafuse and Dr. Donald H. Steinbrecher, is continuing its activities in the area of high dynamic range instrumentation with the completion of a special test set allowing the detection and measurement of distortion products as much as 120 decibels below the desired signal levels. The test set sweeps from 2 to 50 MHz and displays the spectrum as a typical log-amplitude versus frequency pattern. Work is continuing on the all solid-state, 60-GHz receiver with excellent preliminary results on the local oscillator and a 7-decibel conversion loss in the first model of the mixer. The IMPATT diode studies are continuing and a large-signal model has been derived (from small-signal measurements) which describes the oscillating behavior with harmonic impedance control in excellent agreement with experimental evidence. The group is continuing its theoretical and experimental work designed to discover the fundamental performance limits of solid-state devices and the circuit imbedment procedures necessary for the realization of such performances.

The major effort of Professor Rainer Weiss and his students in the gravitational research group during the past year has been the construction of a balloon-borne far-infrared radiometer. The radiometer is to be used in a measurement of the alleged 3°K black body radiation that might be a remnant of the primeval cosmic fireball. The entire balloon package has been tested in a simulated flight; the actual experiment is scheduled for the summer of 1969.

Professor Robert E. Stickney, Dr. Terence J. Lee, and the graduate students in their research group have developed a quasi-equilibrium analysis of high-temperature oxidation of refractory metals. The results of the analysis provide a simple, semiquantitative explanation of existing experimental data. They have also obtained new experimental data on the adsorption, desorption, and work functions of alkali metals, halogens, and oxygen on tungsten crystals. Investigations of the scattering of atoms and molecules from the surface of a tungsten crystal have been conducted, and a theoretical analysis has been made of the permeation of gases through solids. This analysis includes the possibility of the rate being limited by surface processes such as adsorption and desorption as well as by diffusion.

The method developed by Dr. Robert H. Katyl and Professor K. Uno Ingard for studying thermal fluctuations of liquid surfaces by means of light scattering has been applied to the study of a number of liquids and liquid-liquid interfaces. Dynamic values of surface tensions and shear velocities have been determined, and it has been shown that the method permits measurement of smaller values of surface tensions than had been obtained previously.

Charles Krischer and Professor Ingard have developed a new method using light scattering for determination of the attenuation of sound waves in transparent solids at gigacycle frequencies. This method permits the determination of losses that occur at the boundaries of solids.

Professor Hermann A. Haus and his students are continuing their work on laser interaction in carbon dioxide at a wavelength of 10.6 microns. They have demonstrated theoretically and experimentally that gain saturation in a CO<sub>2</sub> laser with optical beam diameters of four millimeters or less is strongly affected by spatial diffusion of excited CO<sub>2</sub> molecules into the beam and of de-excited CO<sub>2</sub> molecules out of the beam. A CO<sub>2</sub> laser oscillator cavity-dumping scheme has been realized producing pulses of the order of 5 kilowatts peak with less than 5 nanoseconds rise times. These pulses are used to study the amplification process in carbon dioxide within times short compared to the inverse bandwidth of the lasing medium and at intensities which lead to appreciable depletion of the inversion in the medium. Professor Haus and Professor Paul L. Penfield

have continued their work on electrodynamics of moving media, resulting in a relativistic formulation for quadrupolar media.

#### PLASMA DYNAMICS

The major goal of the plasma dynamics program is to generate a basic understanding of phenomena in ionized gases and in solids in ways that are relevant to problems such as controlled fusion, space physics, and collective phenomena in solids. The research includes methods of producing highly ionized plasmas by electron beam injection, high-powered lasers, microwaves, low pressure arcs, and so forth.

The plasma physics group is under the supervision of Professors George Bekefi, Sanborn C. Brown, Bruno Coppi, Wallace M. Manheimer and Bradford L. Wright. The research is concerned primarily with linear and nonlinear instabilities and with nonlinear interactions of three or more waves in highly ionized plasmas. In addition, work is in progress toward a better understanding of electromagnetic radiation from plasmas generated by collective interactions of the charged particles.

Professors David J. Rose, Lawrence M. Lidsky, Thomas H. Dupree and their associates continue to develop plasma physics more directly related to nuclear fusion, and fusion itself as a recognizably separate field. For example, in a cooperative program with the Oak Ridge National Laboratory, Professor Lidsky has calculated that any reasonable nuclear fusion reactor will yield a considerable excess of neutrons, which could be used for a variety of purposes. One of the most attractive is to breed fissionable fuel, for example uranium-233 from thorium. Such a symbiosis makes promising certain nuclear fission breeders which appear technically and economically feasible, except that the breeding itself has been too marginal. One such system is the molten salt breeder reactor. Present estimates show that a power economy made up of 90 per cent fission power and 10 per cent fusion power could make a very attractive system.

One of the principal problems of any fusion reactor will be radiation damage by the high-energy (14-MeV) neutrons. With the high power levels, each atom of a vacuum wall facing the fusion plasma will be displaced at a rate approaching once per day. Present 14-MeV neutron sources fail by several orders of magnitude to produce enough flux for proper tests. Professor Lidsky and Denis G. Colombant have completed the preliminary design of a windowless deuterium gas target upon which a 1-ampere 400-keV tritium beam impinges. The 14-MeV neutron flux could be  $10^{14}/\text{cm}^2 \text{ sec}$  in the vicinity, sufficient for meaningful tests to be carried out in a few years.

Professor Lidsky and Masanori Murakami have demonstrated by

very direct techniques the growth and decay of unstable waves in certain plasmas of fusion interest. A beam of electrons is injected down the axis of a long uniform magnetic field, the electrostatic grids are switched on rapidly to trap a section of the electrons. The electrons oscillating axially back and forth in the trap form a very simple one-dimensional plasma in which can be seen the spatial and temporal behavior of a number of waves whose existence had been predicted theoretically.

The active plasma systems group, under the supervision of Professors Louis D. Smullin, Abraham Bers (absent), Keith I. Thomassen, Ronald R. Parker, and Richard J. Briggs, continued basic experimental and theoretical studies of plasma dynamics in a number of areas.

Work by Professor Smullin, Joseph A. Mangano, and Rulon K. Linford on the generation of energetic mirror-confined plasmas by high-power electron beams has concentrated on measurements of the radio frequency spectrum emitted by such discharges, and on the measurement of the energy of escaping ions. A low-power beam-plasma experiment performed by Professor Bers and Bruce R. Kusse used a spiraling electron beam to study instabilities in this configuration, which is common to several controlled-fusion experiments.

Professors Parker and Thomassen successfully stabilized a rotating instability that occurs in a magnetically confined dc discharge by the use of active feedback control. This method of plasma stabilization is of considerable interest at the present time in connection with its possible application to fusion plasmas.

An experimental and theoretical study of spontaneous cyclotron frequency emission from tenuous hot electron plasmas conducted by Professor Bers, Professor Briggs, and Carlton E. Speck has shed light on the very efficient coupling between energetic electrons and microwave fields in highly nonuniform magnetic fields.

All of the plasma groups, comprising physicists, electrical engineers, and nuclear engineers from the Research Laboratory of Electronics, have started a collaborative study with the Francis Bitter National Magnet Laboratory to design toroidal plasma devices suitable for generating a controlled fusion plasma.

#### COMMUNICATION SCIENCES AND ENGINEERING

This research spans a broad range of topics pertinent to communication processes in man-made and living systems, as well as interactions between them. Fundamental studies of signals and systems are coupled with various applications such as speech and picture transmission, seismic detection, and optical communication channels. A major portion of the effort is related to the life sciences. A combined program of research and

training in communications bio-engineering includes areas such as communications biophysics, neurophysiology, cognitive information processing, and speech communication. Much of this work concerns the sensory or perceptual mechanisms. The related program in linguistics seeks to improve our understanding of languages, which form the basis for communication.

The communications biophysics group, under the direction of Professors Walter A. Rosenblith and William M. Siebert, continued its efforts to obtain a better understanding of sensory processes by combining electrophysiological and behavioral experiments with modern data processing and the analytical methods of physical science.

Research in psychophysics, supervised by Nathaniel I. Durlach, has been strengthened by the addition of Professor Julius L. Goldstein to the research staff. Experimental and theoretical work in this area has led, during the past year, to the development of two new theories. The first is based on a particular assumption about a limitation on the way in which the brain makes use of timing information in the auditory nerve, and is applicable to problems of interaural discrimination, binaural detection, and contralateral cueing. The second theory concerns intensity resolution, and unifies the results from a wide variety of experiments on detection, discrimination, identification, and scaling of sound intensity.

The studies of neuroelectric correlates of behavior, under Dr. Robert D. Hall, have recently been focused on the problem of tracing central influences on the motoneurons that mediate eyelid responses in the rat during conditioning. Professor Stephen K. Burns and his students have developed several instruments for the characterization and display of ectopic heart beats appearing in the electrocardiogram. Professor Richard W. Henry and his students have continued their studies of central modulation mechanisms in the proprioceptive control system of the crayfish abdomen. A study of chromatic adaptation in single units of the optic nerve of the ground squirrel was completed by a student of Professor Rosenblith. Studies of baroreceptor firing patterns and of other aspects of the mammalian blood pressure regulatory system were carried out by Professor Peter G. Katona with Dr. G. Octo Barnett of the Massachusetts General Hospital. During the latter half of the year, Professor Lawrence S. Frishkopf joined the group and established a new laboratory facility for the study of hair cells in the lateral line organs of fish and amphibia.

A number of experimental projects were carried out by members of the group in the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary under the general direction of Dr. Nelson Y.-S. Kiang. Professor William T. Peake and his students have carried out further investigations of mechanical motions in the ear utilizing the Mössbauer



effect. Jointly with Professor Peake, Professor Thomas F. Weiss has obtained new results with microelectrodes on the variations of the microphonic potential with location in the cochlea. Professor Michael L. Wiederhold has continued his studies of the olivocochlear bundle and Professor John J. Guinan has shown further correlations between the anatomical and physiological properties of cells in the superior olivary complex.

Professor Jerome Y. Lettvin and his associates in the neurophysiology group report new results on the properties of neural networks. As part of a study which has been conducted over a period of four or five years, Stephen A. Raymond's doctoral thesis examined the effects of axon bifurcation on pulse sequencing. Professor Lettvin and Dr. Shin-Ho Chung had previously shown that multiplexing of information does occur in nerve fibers, and Dr. Raymond's work indicates that the basis for handling multiplexing exists in nerve fibers. Robert J. Bobrow, a graduate student, has used Dr. Raymond's results to make spatial displays that preserve the multiplexed information.

The cognitive information processing group, under the direction of Professor Murray Eden, has continued its studies of the ways by which humans process visual information and concomitant studies on mechanical ways to perform similar cognitive tasks. During the past year substantial progress has been made by Professors Samuel J. Mason, Francis F. Lee and Donald E. Troxel and their students on the development of a reading machine for the blind. The current version can examine text pages of conventionally printed books and produce intelligible synthetic speech at normal human speaking rates.

Professor Eden and Dr. Oleh J. Tretiak, with their associates and students, have pursued a variety of particular image-processing problems of direct relevance to clinical pathology and morphology. Human leukocytes have been successfully classified with a program developed by Dr. Ian T. Young. Dr. James E. Green has shown that many optical and morphological properties of individual erythrocytes can be quantitatively determined by automatic computation based on photographic images of standard peripheral blood smears. Dr. Robert R. Archer has shown that certain morphological aspects of the growth pattern of leaves can be simulated by a model in which a vascular network is imbedded in an elastic continuum.

Professors William F. Schreiber and Thomas S. Huang and their students have devised a procedure for producing holographic filters with the aid of a computer. They have also found that a picture transformed into the Fourier domain can be described by a code with somewhat less than one bit per picture sample point. This represents a very substantial im-

provement in the bandwidth requirement for the transmission of visual information.

Members of the speech communication group, under direction of Professors Kenneth N. Stevens, William L. Henke, and Dennis H. Klatt, have been involved in further studies of the properties of speech events and of the mechanisms for human generation and perception of these events, particularly the perception of the temporal aspects of speech. The capabilities of a digital computer facility for the study and simulation of speech events have been expanded, and this facility has been used to develop procedures for the automatic recognition of simple spoken words, for the identification of attributes that identify particular talkers, for the synthesis of speech, and for the visual display of speech sounds. Among the results obtained in the continuing studies of the production and perception of speech by children has been a description of the kinds of intonation patterns that a child is able to produce during the early stages of language development.

Under the direction of Professors Morris Halle and Noam A. Chomsky, the work of the linguistics group has followed the lines sketched out in previous years. The dispute concerning the need and/or possibility of drawing a sharp line between syntax and semantics, a topic under discussion all over the country, is continuing here in much the same fashion as elsewhere. The dramatic tension of this debate has been an excellent stimulus to our work. The dissertations of Ray S. Jackendoff and Richard S. Kayne represent a number of interesting results.

In other areas of linguistic inquiry the progress has been on a more even keel. There is a great deal of interest in problems of phonological theory, especially questions of rule order. Two dissertations now in progress, by Stephen R. Anderson and Michael K. Brame, mark considerable advances in these domains. The phonological evolution of languages is being studied with great vigor, and this study is beginning to yield interesting and useful results. Finally, important results have been obtained in the study of the phonetic framework. A recently completed dissertation by Nancy H. Woo contains a part of these results.

The information processing and transmission group has been exploring optical communications channels and source coding techniques. Professors Robert S. Kennedy and Estil V. Hoversten and their students are looking at the use of channel-sounding and feedback techniques to improve optical communication through a turbulent atmosphere. Optimum receivers for quantum channels and the transition from classical to quantum channel models are also under investigation. Professor Robert G. Gallager published a book, *Information Theory and Reliable Communication*, a systematic presentation of information theory which contains

many recent research results. He has also continued research on rate-distortion theory. Student thesis work is in process on analog modulation and on cascaded and interleaved tree codes. Professor Peter Elias has been working on quantization.

Professor Donald E. Nelsen and his students have been concerned with random processes that occur in regenerative switching circuits, such as the flip-flop and Schmidt trigger. Models that relate switching-time randomness to the noise processes that occur in these circuits are being investigated. The relationships of these processes to first passage time processes are also being studied.

HENRY J. ZIMMERMANN

### SPECTROSCOPY LABORATORY

The achievements of the research staff of the Spectroscopy Laboratory during the past year included the ruling of the largest diffraction grating of high quality and the determination of laser-excited Raman spectra of a number of proteins for the first time.

The ruling-engine project, under the direction of Professor George R. Harrison, has succeeded in producing gratings that are not only the most powerful optical gratings ever ruled, but are also freer of optical defects than any hitherto available. The B-engine, with capacity to rule gratings up to 18 inches in width, its errors constantly reduced by light waves to fractions of a millionth of an inch, is being turned over to an optical firm capable of producing numerous replicas from each master grating ruled. A major effort is being devoted to development of a still larger interferometrically controlled engine, expected ultimately to produce gratings up to 24 inches in width. Gratings of unprecedented power are now being planned for several astronomical observatories and for a giant M.I.T. spectrograph.

The research group working in the far-infrared region with Professor Richard C. Lord has continued its study of conformational energies in molecules. Potential barriers to molecular inversion have been measured for the first time in several ring molecules with unsymmetrical potential functions by Dr. Lionel A. Carreira. Dr. Dennis W. Wertz has examined the spectra of five-membered rings exhibiting the phenomenon of "hindered pseudo-rotation," and has determined potential barriers to this kind of motion. An interpretation of the complex far-infrared absorption of carbon suboxide has been worked out by Constantin C. Milionis, who devised a computer program for simulating complex spectra in terms of the various anharmonic potential constants involved in such spectra. The

advantages of high resolution and double-beam recording by the Jarrell-Ash far-infrared spectrometer have been essential to successful execution of all of this work.

The study of complex molecules of biological interest has continued. Professor Lord and Nai-Teng Yu have succeeded in the interpretation of the laser-excited Raman spectrum of native lysozyme in aqueous solution in terms of the spectra of the constituent amino acids. Some of the spectral details of the whole enzyme are those of the constituents, some reflect the chemical change from amino acid to polypeptide, and some result from more subtle change in molecular conformation. It is these latter which are of greatest interest and on which future attention will be concentrated. It is planned to investigate the effects on the spectrum of lysozyme produced by thermal denaturation and by interaction with the substrates with which the enzyme interacts chemically. In the far infrared, Dr. Issei Harada has studied the low-frequency spectra of the crystalline nucleic-acid bases 1-methylthymine and 9-methyladenine as well as their one-to-one hydrogen-bonded complex. The analysis of the spectra completed by Dr. Harada and Professor Lord should serve as a partial basis for understanding the far-infrared spectra of DNA and RNA.

Professor Jeffrey I. Steinfeld and his students have continued their work on the application of lasers to optical double resonance in molecules. The 12-meter Czerny-Turner mounting in the Spectroscopy Laboratory has been refitted for scanning and photoelectric recording, and will be used in an ultraviolet-infrared double resonance study of propynal vapor, using a  $\text{CO}_2$  laser excitation source. Work is also under way on analysis of the 10.6-micron band of  $\text{SF}_6$ . This band absorbs  $\text{CO}_2$  laser radiation very strongly, but the rotational state involved in the transition is unknown because the band is unresolved. Band-contour analysis is being carried out in an attempt to identify the rotational state involved.

During the past year Professor Ali Javan and the optical and infrared laser group have emphasized application of modern spectroscopic techniques in precision studies of a variety of atomic and molecular processes. The nonlinearities of atomic and molecular resonances are utilized to obtain considerable narrowing of the spectral line profiles, enabling in some cases orders of magnitude improvements in resolution and accuracy. These techniques have made possible precision measurements of Stark splitting — by an amount considerably less than the overall Doppler line profiles — in the excited vibrational states of molecules, and also precise measurements of fine and hyperfine structure of a number of important atomic and molecular resonances. A variety of effects are also explored in the general area of molecular energy transfer and vibrational relaxation in gaseous systems; these include detailed studies of molecular collisions

leading to near-resonant vibrational excitation transfer and diffusion of vibrational excitation. High-resolution spectroscopic studies are also carried through on ultraviolet laser transitions in molecules under conditions where various transitions are amplified by an enormous amount, leading to significant traveling-wave line-narrowing effects. Other research topics include the application of newly developed techniques of absolute frequency measurement in the far infrared in fundamental problems in length and time standards.

The Laboratory gave its annual Special Summer Program in the technique and applications of infrared spectroscopy for the 20th time in June, 1969. The number of alumni of this program is now about two thousand. Many of these men and women have done distinguished work in the application of infrared spectroscopy to their own research fields, which include space science, astronomy, medicine, and air pollution as well as physics, chemistry and biology.

Visiting scientists working in the Laboratory during the past year included Dr. Issei Harada, University of Tokyo, and Dr. Dennis W. Wertz, University of South Carolina.

RICHARD C. LORD

### URBAN SYSTEMS LABORATORY

In the first full academic year in the life of the Urban Systems Laboratory (U.S.L.) there was much and varied activity. By design, the year was to be primarily one of individual faculty-oriented, developmental-type projects in the urban area. These activities were to be discipline-based and under the direction of U.S.L.'s Associate Directors. At the same time, encouragement and other forms of support were to be given to those project leaders who had shown evidence that they could mount interdisciplinary, mission-oriented efforts. It was hoped that these latter projects would involve graduate and undergraduate students. Moreover, efforts were aimed at direct participation and community involvement. Finally, there was considerable deliberation concerning the organizational structure of U.S.L. in view of an imminent change in the mix of activities, the provision of grant and contract funds, and additional space for expanding project teams.

This multiplicity of activities helped us to sharpen and have confidence in the major objectives of U.S.L. Our ultimate aim is to provide a mechanism and framework by which the expertise and skills of faculty, staff, and students at M.I.T. can interact with the evolving and dynamic needs of individuals and groups in the urban area. If this is to be done with the impact which Institute activities have had on industry and

federal government activities, the efforts must be multidisciplinary. The urban problem, by definition, requires a wider array of intellectual resources than are available at M.I.T. Therefore, the physical science-based, social science-based, and the aesthetic-based disciplines within the M.I.T. structure must collaborate if we are to create an impact on even a limited number of urban systems. We are aware that this has never been accomplished; we believe that the importance of the task requires us to try.

At the same time, we believe that these interdisciplinary groups ought to be engaged primarily in "understanding for change" rather than in "understanding for the sake of understanding." This implies that we must have urban clients who are willing to share with us their problems and who will be willing to implement the alternative solutions which are likely to be developed within project teams at U.S.L. This can be difficult to achieve in the urban area, since the urban client generally does not have the financial means to support contract research. Nevertheless, his involvement is critical and must be assured just as if he were using his own critical dollars to pay for the research.

Several of the current projects of U.S.L. are moving toward these ultimate objectives. Project CARS (Computer Aided Routing Systems) comprises 70 members from the faculty, staff, and student body of four departments and four laboratories, who are blending their skills to develop a transportation system featuring minibuses which will be routed by a computer according to consumer demand. Initially, the demonstration of this system will occur in a low-density area where the consumers will be able to phone for pick-up at their doors and get delivery to a single major point. In ensuing demonstrations, there will be delivery to multiple points. This project is being financed currently by the Department of Housing and Urban Development, the Department of Transportation, and Ford Motor Company.

Project Transportation and Community Values is concerned in its broadest sense with applying multi-modal analysis to the problem of moving people and goods in the metropolitan areas. More narrowly it is concerned with the development of "environmental indicators," which taken together with the more traditional economic, location, and design indicators, would allow us to evaluate the impacts of alternative urban highway locations and designs.

The project team led by Professor Marvin L. Manheim of Civil Engineering includes 20 members of the faculty, staff, and student body from five departments and two laboratories. This project is being funded by the National Cooperative Highway Research Program, a joint effort of the U.S. Bureau of Public Roads and the American Association of State Highway Officials.

Professor Manheim has written: "The proposed approach to evaluation attempts to strike a balance between the use of numerical 'scoring' techniques, and the desire for wide community participation in the decision-making process. We begin with the premise that transportation is essentially discriminatory: each alternative will benefit some groups at the expense of others. From this arises the hypothesis that the role of the technical team doing the highway location and design is to clarify the choice issues for the polity and bring about effective community consensus on an equitable course of action; to identify the options and their impacts on different groups, to interact with the community to stimulate constructive discussion of alternative actions and alternative objectives, to search for imaginative technical solutions which might be more equitable in their impacts on various interest groups; and to stimulate constructive negotiation among interest groups to achieve equity through compensation, improved technical designs, and other means.

"The proposed evaluation approach attempts to do this in several ways. First, the location team will supplement its 'technical' activities with community interaction activities, which, if nothing else, will at least sensitize the team to the interests in the community. Second, a phased strategy is suggested, which may prove workable in structuring the interactions between technical team and community to achieve a consensus on an equitable course of action."

Project CARS and Project Transportation and Community Values are examples of interdisciplinary projects which were initiated in the M.I.T. community and for which funding and clients were sought outside. Project New Communities, by contrast, represents an interdisciplinary team which was put together to meet the specific needs of an urban client, the Boston Redevelopment Authority (BRA), which was concerned about the possibility of building a new community on the proposed Expo '76 site, either before 1976, so that the Expo would be a culmination of the new community, or after 1976 as a reuse of the site.

Many questions were raised during the BRA study which went beyond that study. Do new towns represent an effective way of handling a population growth of 2,000,000 Americans per year? Where should these towns be located? By what process do you design and plan, operate, and evaluate new towns? The project team concluded after an intensive summer of study in 1969 that "new communities would become a major component in a strategy to deal with current urban problems and future urban growth in this country. At the same time, it appears that the country is not prepared to undertake this task." As a part of this preparation, the group foresees the needs for a commitment by "the federal government in this sphere and the training of qualified professionals who will be com-

petent to deal with specific new towns problems. In an effort to meet the need for trained professionals knowledgeable in the new community planning and capable of interdisciplinary understanding, we have begun a project which should also produce significant contributions to the body of conceptual and theoretical information on the subject and technical equipment to implement new communities."

A substantial portion of the volume of the work of U.S.L. in 1968-1969 was discipline-based and under the direction of U.S.L.'s six Departmental Associate Directors: Professor Ithiel D. Pool, followed by Professor Alan A. Altschuler, for Political Science; Professor Richard L. de Neufville, working with Professor Charles L. Miller, for Civil Engineering; Professor Aaron Fleisher for City and Regional Planning; Professor Mason Haire for the Sloan School of Management; Professor Donlyn Lyndon, followed by Professor William L. Porter, for Architecture; and Professor Jerome Rothenberg for Economics. Most of last year's Annual Report was devoted to their efforts in this regard.

A sample of projects from the departments should serve as an indicator of the rich variety of activities going on. Several faculty members from Political Science under the leadership of Professor Altschuler worked with the administration of Boston Model Cities on Decentralization in Urban Government. This work, which was both conceptual and substantive in nature, led eventually to recommendations as to which portions of several municipal services are most amenable to decentralization and which are not.

Dr. William Jobin of the staff of the Civil Engineering Hydrodynamics Laboratory worked on "Rat Control — A Strategy for Boston." A mathematical model was created, simulating an urban rat population under environmental conditions such as those found in the alleys of Boston. The model was then used to predict the effects of three programs — poisoning, garbage control, and control of nesting areas. According to the economic analysis performed, control of nesting was the least expensive of the three programs evaluated. The project group also concluded that to control rats we must either increase our monetary commitment or decrease the cost of our programs.

Professor Jay W. Forrester of the Sloan School of Management and his colleagues have been working on the dynamics of social systems with a focus currently on urban problems and the dynamics of urban interactions. The recent publication of *Urban Dynamics* (M.I.T. Press) is a result of Professor Forrester's long-standing interest and his close collaboration with Professor John F. Collins and other urban clinicians. Currently, this research is being expanded and application begun.

Finally, work on the development of an architecture machine, a spe-



cial-purpose satellite device with local memory and local processing ability, capable of interacting with the Institute's large IBM machine, the 360/67, is being developed by Professors Nicholas P. Negroponte and Leon B. Groisser with U.S.L. support.

In some ways, urban unrest and student unrest are connected. At least many students now view urban-oriented involvement as relevant and socially desirable, and their involvement in U.S.L. projects has always been high among our priorities.

In this regard, several efforts deserve mention here. At the beginning of the academic year, Professor deNeufville and Mr. Henry W. Bruck, Associate Directors of U.S.L., made special efforts to make known to the members of the student body the variety of projects which were under way in U.S.L. and to obtain information and reaction from the students, by questionnaire and personal interview, to serve as indications of student interest to faculty members. An undergraduate was appointed to help with this project, in the particular hope that undergraduate interests could be discovered, defined, and channeled into existing or new projects.

Graduate students assumed important roles in the design and operation of several projects. For example, a group of 10 graduate students constituted a seminar to study systems models of urban development in general and Professor Forrester's Urban Dynamics model in particular. After the seminar some of the students have continued to work in the area of inquiry even up to this time.

During the spring, an alumnus of M.I.T. talked to staff members of U.S.L. concerning the challenge of growth in small towns on the urban fringe. The alumnus was a selectman of one of these towns, which had grown rapidly and expected continued rapid growth due to the unused land within the town limits and the town's favorable location. The opportunity to work on the problems and the possibilities of a small, growing town brought a new dimension to the work of U.S.L. During the summer, 10 graduate students from the Department of City and Regional Planning worked with the town selectmen and planning board on problems created by growth. Recommendations have been submitted by the students, and they are following up to see how these recommendations are dealt with.

U.S.L. also responded to a proposal for a Research Task Force composed of faculty, staff, and students, predominantly from the Department of City and Regional Planning. The task force established criteria and priorities for allocating funds to students, who were pursuing their own specific research interests during the summer. In addition, at the end of the summer each student was required to submit a final report, and the task force submitted a statement evaluating this experiment.

A small but essential part of the Institute's response to the urban problem has been the direct participation of faculty and staff in urban agencies. It would be impossible to record this involvement adequately. Nevertheless, staff affiliates of U.S.L. are called upon from time to time to assist individuals and community agencies, and we should call attention to some of these.

Professor Miller, Director of U.S.L., was asked to become chairman of the Transportation Task Force for President-elect Nixon. Several staff affiliates of U.S.L. served in various staff capacities for varying periods of time during that effort. In addition, U.S.L. provided staff and financial support to a Sub Task Force on Economic and Social Concerns, the chairman of which was Mr. Melvin H. King, Executive Director of the New Urban League of Boston. Mr. King called together a small group of representatives of the poor to discuss the consequences of past transportation policies for these groups and, more importantly, to make recommendations about new policies which would make "mobility a right for all."

As an outgrowth of this initial relationship, U.S.L. entered into a cooperative relationship with the New Urban League to hire mutually a housing specialist who would work under the structure of the League using the resources of U.S.L. in his work. The housing specialist has been particularly interested in the process of rehabilitating low-cost housing and in protecting the rights of tenants in such housing.

Finally, staff members of U.S.L. have worked with citizen groups on the general problem of how technology, by and large a national and international means at this time, may be made applicable to their needs. These efforts have taken place in collaboration with other formal and informal groups at M.I.T. and in direct relationship with citizen groups.

#### A LOOK AHEAD

During the summer of 1969, an agreement was made allowing U.S.L. to occupy the first two floors of the Webster Building, an industrial site located at Amherst and Wadsworth Streets and recently acquired by M.I.T. Approximately 30,000 square feet of floor space will be provided for project teams in this location. Webster, now M.I.T. Building E-40, combined with our space on the fifth floor of Building 9, should prove adequate for U.S.L. needs for an interim period.

With space removed as a critical obstacle, we must focus on funds as the most pressing need for the continued operation and growth of U.S.L. There is a need for both grant and contract funds from public and private sources. Clearly, the current preoccupation with defense and space efforts and the need to manage the nation's inflation have a critical

impact on federal efforts in the area of urban research. The foundations, the largest prospective source of grant funds in the private sector, have their own set of problems, including maintaining helpful urban programs for which there has been dwindling support at the federal level. Nevertheless, we must find ways to support U.S.L. or suffer immense cutbacks at a flowering stage.

We must also continue our search for institutional mechanisms which will increase the temporary but necessary "horizontal pull" of U.S.L. vis-a-vis the "vertical pull" of the departments. Nor can this "horizontal pull" be monolithic, for the mechanisms which work for one department or one person may not work for another. So far we have used grant funds, and we have capitalized on the enormous interest in urban problems. We need more tools which are consonant with the Institute's long range interests.

Finally, we must take steps to expand our linkages with public and private groups whose interests, resources, and competence extend our own in vital areas. In this regard we are pleased to have recently agreed to work with Metropolitan Applied Research Center, Inc. (MARC), a private non-profit group in New York City. Dr. Kenneth B. Clark is president of this agency, which is concentrating on problems of race and poverty, major components of the modern urban problem in America today. It is our hope that this relationship will be the forerunner of other successful relationships with outside agencies and organizations.

CHARLES L. MILLER

FRANK S. JONES



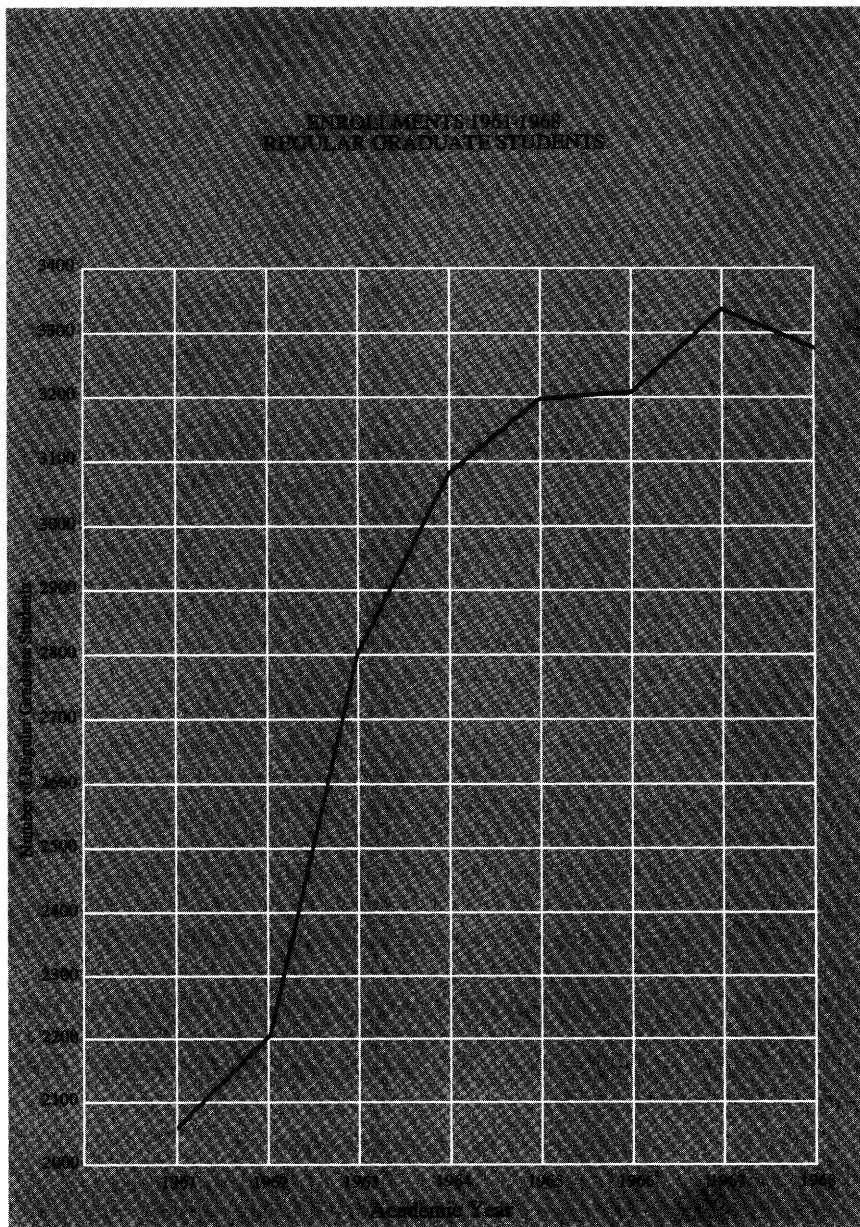
## GRADUATE SCHOOL

**D**uring the last few years, and especially in 1968-69, the Graduate School at M.I.T. has become much more integrated into the life and interests of M.I.T. The pattern of a student's graduate education in the past involved his highly specialized professional training in advanced subjects and research. With the exception of intramural athletics, his participation in Institute affairs was minimal. During the last year, however, graduate students have become involved in activities such as community service, education of disadvantaged students both at M.I.T. and in Greater Boston, the governance of the Institute, policy on research projects sponsored by the Department of Defense, ROTC policy, and a host of other interests. In most of these extracurricular activities, graduate and undergraduate students have cooperated closely and effectively. With this important change in the role of the graduate student which has taken place recently, the student receives a broader education than ever before, and this has occurred without a deterioration in the quality of his professional training. In some cases, however, the time required to obtain a graduate degree has been prolonged somewhat. During the coming year, the situation will be carefully monitored and action taken to make certain that these new trends in graduate education result in a person who is better trained to contribute to the solution of both professional and general problems of society.

### ENROLLMENT OF GRADUATE STUDENTS

For a long period of time the Graduate School has grown consistently at a rate of about 5 per cent per year. In recent years, growth rate was limited to 3 per cent per year in order to conform to the overall pattern of expansion of M.I.T. However, the enrollment picture changed abruptly

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in the fall of 1968. There were only 3,274 regular graduate students registered as compared to 3,344 for 1967 — a decrease of 1.9 per cent compared to the usual increase of 3 per cent. This decline in enrollment is not yet reflected in the number of graduate degrees awarded; they continue to increase (1,211 for 1967-68 as compared to 1,346 for 1968-69).

The decline in enrollment was not unexpected, and indeed might have been much more serious had not many departments overadmitted students in the spring in anticipation of attrition by the fall of 1968.

The major cause for the decline in enrollment appears to be the changes in Selective Service regulations in the summer of 1967 which resulted in the drafting of graduate students beginning in 1968. Although some students were inducted into the armed services, a much larger number failed to register in the Graduate School for other reasons related to Selective Service policy. In this respect the enrollment in the School of Engineering was especially curtailed because engineers in particular could accept positions in industry which might provide occupational deferment.

Another important factor contributing to the decrease in enrollment was the curtailment in Federal graduate fellowships and research assistantships supported by Federal research grants. The outlook for graduate enrollment in the fall of 1969 is discouraging primarily because of Selective Service, but also due to lack of Federal support for graduate students. We anticipate that it might drop as much as 5 per cent below the 1967 enrollment, despite a policy of overadmission in most departments.

#### FELLOWSHIPS, SCHOLARSHIPS, AND ASSISTANTSHIPS

The support of graduate students by fellowships, scholarships, and assistantships has continued at a high level during the past year, with 90 per cent of the students receiving full or partial financial aid. Nearly half of the graduate students were employed by M.I.T. as research or teaching assistants and about one-quarter of the total were supported by Federal fellowships from several different agencies. Many of the remainder received aid from industry, foundations, or foreign sources. A small number, who could not obtain sufficient financial support, were awarded loans from the Technology Loan Fund. A summary of the major types of financial support for graduate students is presented in the accompanying tables (see Tables III, IV, and V).

Compared to the previous year, the funding of graduate education has become more critical because of increased tuition, fees, and living costs, and a decrease in Federal fellowships to graduate students and research grants to faculty for the support of research assistants. The outlook for the coming year is not encouraging, for it now appears that Federal

support for graduate education may be curtailed even further as a result of budgetary restrictions being implemented in Washington. For this reason, it will be necessary for M.I.T. to search for new funds from industry and foundations to support graduate students. In the meantime, special funds from the academic budget have been allocated to the Graduate School office for tuition scholarships to be used in solving emergency financial problems of highly qualified students.

#### NEW ACADEMIC GRADUATE PROGRAMS

A new graduate joint degree program in the area of oceanography was inaugurated in 1968 with the Woods Hole Oceanographic Institution (W.H.O.I.). Graduate students may take an integrated program of subjects and research at both institutions leading to an advanced degree. The graduate deans of M.I.T. and W.H.O.I. have general responsibility for the cooperative effort in operating the program. There is also a committee, consisting of administrators from the two institutions, which provides guidance on policy matters. The doctoral program in oceanography involves faculty from the Departments of Meteorology and Earth and Planetary Sciences at M.I.T. as well as faculty from W.H.O.I., and is supervised by a joint faculty committee from both institutions. Similarly, the new program in ocean engineering, leading to the professional degree of Ocean Engineer, or a doctorate in ocean engineering, is supervised by faculty from the Department of Naval Architecture and Marine Engineering at M.I.T. in conjunction with faculty at W.H.O.I. In the case of ocean engineering, any M.I.T. graduate student may apply to the faculty committee for permission to take a subject at Woods Hole, whether or not he is registered for the degree program.

A cooperative arrangement for cross registration in graduate subjects between Brandeis University and M.I.T. became operational in February, 1969. The agreement is limited to graduate students taking subjects in the Department of Urban Studies and Planning at M.I.T. and the Florence Heller Graduate School for Advanced Studies in Social Welfare at Brandeis.

A new interdepartmental doctoral program between the Departments of Economics and Urban Studies and Planning has been approved, beginning in June, 1969. A standing committee, composed of faculty members from the two departments, has been set up; it will lend supervision and guidance to graduate students who wish to pursue a doctoral degree involving both economics and urban studies.

#### SELECTIVE SERVICE

The Draft Act of June, 1967, called for the cancellation of deferment for all graduate students who entered graduate school (except in medi-



## GRADUATE SCHOOL

cal fields) after September, 1967. Hence, by September, 1969, first-, second-, and third-year graduate students are eligible to be drafted. To deal with problems presented by Selective Service at M.I.T., a special committee, under the chairmanship of Associate Dean Sanborn C. Brown, was appointed by President Howard W. Johnson. This committee is concerned with policy matters and supervises both the graduate and undergraduate Selective Service offices which have been set up to counsel students on their individual problems relating to the draft.

Special attention has been devoted to the problem of possible deferments for students taking a combined S.B.-S.M. program who, in their fifth year, are registered in the Graduate School but are considered by Selective Service Boards to be undergraduates and not eligible to be drafted since they have not completed all the requirements for a Bachelor's degree. Another group considered for occupational deferment is the graduate students who are employed as full-time teaching assistants. In certain cases, a graduate student who is carrying on research of critical importance to the national interest can also be recommended for occupational deferment by his faculty supervisor.

For many different reasons, the number of graduate students from M.I.T. inducted into the Armed Forces has not been large to date. However, many students have left the Graduate School, or decided not to enroll at all, for reasons related to Selective Service. It is expected that graduate schools will be more seriously affected during the coming academic year and that inevitably a shortage of manpower holding advanced degrees will develop soon. Steps should be taken to change the draft laws perhaps along the lines proposed by President Nixon in his recent message to the Congress to alleviate this critical situation, which will result in a serious deficit of professionally trained men.

### GRADUATE STUDENT AFFAIRS

A leading role in the management of matters of special interest to the graduate student is played by the Graduate Student Council. This group is made up of representatives from each department plus delegates from several living groups. Officers of the Council work closely with Associate Dean Robert J. Holden of the Office of Student Affairs as well as with the staff of the Graduate School office. Two members represent the Council at meetings of the Committee on Graduate School Policy, and, in addition, the Council nominates graduate students to serve on certain subcommittees of the Graduate School. The Graduate Student Council has a permanent office in the Walker Memorial Building. A social center, under its auspices, The Muddy Charles Pub, in the same building, provides a

## GRADUATE SCHOOL

meeting place for faculty and graduate students who wish to discuss academic or other matters in an informal atmosphere.

### GRADUATE STUDENT HOUSING

Despite the recent completion of Eastgate for housing of married students, the problem of living facilities for graduate students remains critical. Under the leadership of Dean Kenneth R. Wadleigh and Vice President Philip A. Stoddard, plans have been made, with the cooperation of the Dean of the Graduate School and the Graduate Student Council, for the construction of a high-rise building in the Westgate area. This building will provide housing mainly for single graduate students. Although financial arrangements and architectural design are not yet complete, there is good reason to believe that construction could begin in the latter part of 1970.

### BLACK GRADUATE STUDENTS

Historically, the enrollment of students from minority groups in the Graduate School at M.I.T. has been low. Hence, during the past year special efforts have been made to recruit larger numbers of such students. A subcommittee of the Committee on Graduate School Policy was appointed to deal with this matter and as a result of its efforts, some 20 black institutions were contacted and 13 were visited by faculty, black graduate students from M.I.T., and staff of the Graduate School office. The activities concerned with the recruitment of black graduate students have now been integrated with those dealing with undergraduates. Michael S. Baram, Executive Officer of the Graduate School, has worked with the M.I.T. Task Force on Educational Opportunity, chaired by Associate Provost Paul E. Gray. He has also worked on these matters in association with the Black Student Union. As a result of these diverse efforts, a modest increase in black graduate student enrollment, especially in the Departments of Physics and Urban Studies and Planning, is anticipated in the fall term of 1969.

### NEW EDUCATIONAL POLICIES

#### LANGUAGE REQUIREMENT FOR THE DOCTORAL DEGREE

For several years the Committee on Graduate School Policy has reviewed the requirements for foreign languages for the doctoral degree. A questionnaire to the faculty, plus discussions with graduate students and the Department of Foreign Literatures and Linguistics, all were crucial in reaching a decision. It was decided that steps should be taken to advise each graduate student that competence in one or two foreign languages

#### GRADUATE SCHOOL

should be achieved as an undergraduate. For those students who must take a foreign language while at M.I.T., it was voted that a two-term subject would be required, with emphasis on either conversation or reading of professional literature. However, in view of the very different needs in the various graduate programs, it was decided that each department should determine its own language requirement. It now appears that nine departments probably will require competence in a foreign language for the doctoral degree.

#### CLASSIFIED THESES

Since World War II, it has been possible for a graduate student, under special circumstances, to choose a thesis research problem sponsored by a grant or contract from the Federal Department of Defense. Occasionally the completed document might be classified and made unavailable to the general public. After several meetings devoted to considering various aspects of this problem, the following was approved:

The Committee on Graduate School Policy considers it undesirable that a student should choose a thesis likely to be classified as "Confidential" or "Secret" for reasons of national security, or restricted for proprietary or other reasons, and *no student is permitted to embark on such a thesis.*

In the future, in the event that a government agency does not permit immediate publication of a thesis, a subcommittee of the Committee on Graduate School Policy will investigate the matter to determine what steps must be taken to ensure eventual publication.

#### THESIS IN ABSENTIA

Under certain circumstances, it is necessary for a graduate student to pursue part of his thesis off campus, although still working toward a degree under the guidance of a faculty member at M.I.T. Permission is granted for such a thesis in absentia only after a review by a special subcommittee of the thesis proposal and circumstances surrounding the request. Such a student, who remains registered at M.I.T. while not in residence, may be given the appointment of Traveling Fellow. The purpose of this appointment is to aid the student in establishing his credentials while working in a foreign country on his thesis research.

#### PERSONNEL

During the past year, Associate Dean Sanborn C. Brown has been on sabbatical leave sponsored by the Guggenheim Foundation. He will resume his duties in the Graduate School in September, 1969. Robert K. Weatherall will continue his position as Assistant Dean of the Graduate School in addition to his new appointment as Director of Placement. He

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will devote most of his time to the placement of degree candidates at M.I.T. or other universities, as well as in industrial or government positions.

IRWIN W. SIZER

Table I-A Graduate School Quotas and First-Term Registration, 1968-69

	All Schools	Engineering	Science	Architecture and Planning	Humanities and Social Science	Management
Quota	3,342	1,630	1,006	132	274	300
Registration	3,274	1,541	1,014	144	266	309

Table I-B History of Quotas and Registration, All Schools, 1964-1968

	1964	1965	1966	1967	1968
Quota	2,963	3,084	3,232	3,342	3,342
Registration	3,087	3,196	3,198	3,344	3,274

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**Table II Graduate School Statistics, 1968-1969**

Advanced degrees conferred	B.Arch	M. Arch. and M.C.P.	S.M.	Engineer	Sc.D.	Ph.D.	Total
September, 1968		36	248	17	13	103	417
February, 1969		4	175	25	28	110	342
June, 1969	6	8	329	84	23	137	587
<b>Total</b>	<b>6</b>	<b>48</b>	<b>752</b>	<b>126</b>	<b>64</b>	<b>350</b>	<b>1,346</b>

Graduate school registration (Includes Regular and Special Students)	Summer, 1968	Fall, 1968	Spring, 1969
School of Engineering	1,037	1,871	1,644
School of Science	747	1,086	996
School of Architecture and Planning	51	194	182
School of Humanities and Social Science	113	305	293
Alfred P. Sloan School of Management	92	353	328
<b>Total</b>	<b>2,040</b>	<b>3,809*</b>	<b>3,443</b>
Regular Students	1,978	3,274	3,014
Special Students	62	535	429

\* 3,037 = U.S. and Canadian students  
772 = Other nationalities

**Table III Summary of Graduate Financial Assistance for 1968-69**

Total Regular Graduate Students	3,274
Federal fellowships and traineeships	797 (24%)
Graduate student staff	1,555 (48%)
Industrial and foundation awards	114 (3%)
M.I.T. endowed and budgeted funds	69 (2%)
Students sponsored by external sources	427 (13%)
<b>Total awards</b>	<b>2,962 (90%)</b>

## GRADUATE SCHOOL

**Table IV Graduate Student Support**

The sources of support for most of the 3,274 M.I.T. graduate students in 1968-69 are listed. However, a single table is an incomplete reflection of the total picture, since support constantly shifts and changes throughout the academic year in accordance with changing student status, early termination of degree program, the draft, and so on. To diminish the statistical problem created by this constant change, this table was devised to present a "snapshot," in effect, taken in October, 1968.

## Fellowships and Traineeships awarded by M.I.T.

National Aeronautics and Space Administration Traineeships	24	
National Defense Education Act Traineeships	137	
National Science Foundation Traineeships	151	
National Institutes of Health and other Health, Education, and Welfare (HEW) Traineeships	116	
Industrial and Foundation Fellowships	85	
M.I.T. Endowed and other Fund Fellowships	69	
Total		582

## Fellowships awarded by sponsors to M.I.T. students

Atomic Energy Commission Fellowships	36	
National Science Foundation Fellowships	245	
National Institutes of Health and other HEW Fellowships	74	
National Aeronautics and Space Administration International Fellowships	6	
Housing and Urban Development Fellowships	7	
National Defense Foreign Language Fellowships	1	
Woodrow Wilson Fellowships	2	
Hertz Foundation Fellowships	21	
Danforth Foundation Fellowships	6	
Total		398

Student Assistantships — Research and Teaching 1,555

## Sponsored Students

In addition, many students are known to be receiving partial or full support from employers and sponsors. The following reflects Bursar's billings for tuition to such employers and sponsors.

U.S. government agencies	288	
Industry and foundations	84	
Foreign countries and international programs	55	
Total		427

Total: Students receiving full tuition and stipend awards or otherwise believed to be fully supported

2,962

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**Table IV (Continued)**

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**Partial awards, loans, and miscellaneous programs**

Individual student support in many cases is derived from partial awards ranging from \$100 to \$3,000 each. In a few such cases, an accumulation of partial awards provides a student with essentially complete support. As a result, the number of such partial awards does not reflect the number of student recipients.

**Full tuition awards**

Sloan Executive Fellows	50	
M.I.T. Endowed and Special Budget	61	
Industrial and foundation	18	
<b>Total</b>		<b>129</b>

**Partial tuition awards**

M.I.T. Endowed and Special Budget	26	
Industrial and foundation	11	
<b>Total</b>		<b>37</b>

<b>Recipients of M.I.T.-administered loan funds</b>	<b>580</b>	
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National Science Foundation Summer Traineeships	13	
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<b>Total</b>		<b>759</b>
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GRADUATE SCHOOL

Table V Federal Support for M.I.T. Graduate Students

	Atomic Energy Commission	Housing and Urban Development	National Aeronautics and Space Administration	National Defense Education Act	National Science Foundation Fellowships	National Science Foundation Cooperative	National Science Foundation Traineeships	Total
1951-1952					48			48
1952-1953					46			46
1953-1954					51			51
1954-1955					61			61
1955-1956					64			64
1956-1957					64			64
1957-1958	26				92			90
1958-1959	35			4	100	39		127
1959-1960	43			14	102	40		186
1960-1961	39			25	152	42		195
1961-1962	39			29	165	44		258
1962-1963	34		15	32	178	53		272
1963-1964	35		30	28	206	58		313
1964-1965	41		45	40	207	55	79	442
1965-1966	27		45	72	231	8	114	488
1966-1967	30		39	131	230		132	518
1967-1968	45	3	24	137	245		146	594
1968-1969*	36	7					151	600

This table does not include data on the continuing National Institutes of Health fellowship and traineeship programs which had their inception in the 1940's.

\* Not included in table: 6 NASA International Fellowships, 74 NIH Fellowships and 116 NIH Traineeships for 1968-1969.



## **VICE PRESIDENT ACADEMIC ADMINISTRATION**

**T**he complete reports which follow from those offices which are responsible administratively to the Vice President, Academic Administration, accentuate the great urgency of the many challenges that came to us during the last academic year and serve as an indication of the more intense demands to come in future months. I mention a few of the highlights of the reports.

1. Student activism reached greater proportions during the year than ever before, with a continuing effort on the part of the administration to meet each proposal in the best way possible. Student housing continues to be a prime concern. Our efforts to increase housing capacity are gradually being realized with the nearing completion of the MacGregor House. Other plans for improving the quality of existing facilities continue to develop, however, we are still faced with a serious shortage of housing space.
2. Notable in the area of Student Aid has been the yearly effort to make an M.I.T. education possible to all students qualified for admission, in spite of an increase in tuition and a consequent increase in the number of students needing aid. However, we have been disturbed by the realization that available sources of scholarship aid did not increase during the year as much as in previous years.
3. Our Admissions Office has reported a greater number of freshman applications for the year and an excellent percentage of actual registration. In particular, a special program has had encouraging results in making an education at M.I.T. available to bright students, regardless of minority group backgrounds.
4. The Office of Personnel Relations included in its many activities of this year a program for recruiting new employees from minority groups.

It is expected that this program, in cooperation with the Opportunity Development Office, will grow to greater proportions during the coming year.

5. The Medical Department is continuing to develop its services, despite severe space restrictions. Its forthcoming expansion to the former Sancta Maria Hospital building will alleviate this situation only temporarily.

6. As I have reported in past years, the critical need for expanded undergraduate housing has directly influenced the availability of capital funds for needs outside of the academic program. The most obvious area where funding has not been met continues to be the Department of Athletics, whose needs are outlined by Professor Ross H. Smith in his report.

MALCOLM G. KISPERT

### DEAN FOR STUDENT AFFAIRS

In my report to the President last year, I chose to focus attention on only two of the many broad areas of concern to the Dean's office, student activism and student housing. Again, for this year's report, although many additional topics have been of considerable concern to the dean's staff, I believe it is appropriate to concentrate on that set of issues, which, for a lack of a better title, I shall call "unrest" and on student housing.

In the reports of members of the staff which follow and in the report of the Provost in another section, several other areas of importance are described. I note, in particular, the Institute's new programs for black and other disadvantaged students; our efforts to develop more effective counseling programs; several significant changes in the freshmen orientation, residence, and academic programs; the further development of programs by the Graduate Student Council and by all student activities, particularly those focused on off-campus teaching and social service; and the ever-increasing demand for new and expanded facilities to meet this community's expanding interests in music, drama, and athletics.

#### UNREST

Last year, in addition to presenting a chronology of events falling under the category of "unrest," I attempted to highlight and interpret those characteristics of the Institute which enabled us to come through 1967-68 somewhat breathless to be sure, but I think all the stronger for our experiences. I also attempted to legitimize, if only partially, many of the student actions which not too long ago would probably have been regarded as outrageous by all members of the M.I.T. community. To place in context the events of the year currently coming to a close and our

responses to them, I shall review very briefly our so-called "Dow Day" of November 1967.

M.I.T. had not experienced open protest prior to that time. (We had had, of course, "tuition riots" and "panty raids," but I think it would be safe to characterize these latter events as a form of young males' spring-time fertility rites and not as serious protests.) As we faced an announced intent to protest the visit of Dow Chemical Company recruiters to our Placement Office, we had to recognize that, like it or not, those individuals who wished to oppose this country's national policy in the Vietnam war were frustrated by their inability, in their view, to be heard by the Federal government. This sense of frustration seemed to peak at the undergraduate college age population where the influence of the draft on careers and life itself was greatest and where there was not even the opportunity to exercise the right to vote to influence a change.

Thus, those of us with administrative responsibilities recognized not only the legal right but, I would claim, the moral right of student groups to picket or in other orderly ways seek to bring attention to those issues about which they felt so keenly. On the other hand, we also recognized that no matter how peaceful and orderly the leaders of any such event might desire it to be, mob action, overly-zealous participants, and, frankly, in some cases, the presence of agitators with the objective of inciting violence, were great risks. Finally, we had to recognize our responsibility to take whatever steps were necessary to insure non-interruption of the primary business of the Institute and to insure the safety of our entire community.

As we faced the impending Dow situation, we were caught in the dilemma of attempting to balance what appeared to be possibly irreconcilable principles — and to do so in an atmosphere which would be safe, not because the community had a police force of overwhelming power available for instant action, but because the self-discipline of the members of the community made it so. President Howard Johnson's statement issued on November 4, 1967, described this dilemma and set forth the Institute's policy. He said, in part:

I am well aware that questions as to the appropriateness of some applications of these principles should be opened to discussion by students and faculty. But the way to consider such matters is by the kind of discussion appropriate to our open community and not by denying or damaging the rights of others. To infringe upon the rights of either protesters or those who seek information about jobs, inflicts grievous damage on the integrity and the long-run quality of the academic community.

Finally, let me say, the university should not be put into the position of meeting force on the part of people who abuse the privileges of the academic community. We have to rely therefore on the good sense and self-discipline of all of our members. I believe we can do so at M.I.T.

The succeeding events indicated that our community was successful in achieving four objectives: (1) dissent occurred, but in a fashion which at once drew attention but was not violent; (2) the business of the Placement Office and of M.I.T., although clearly influenced and disturbed, was not truly interrupted; (3) what appeared at the outset to be a dilemma was turned to an educational experience, for example, the open forum held at noon on the date of the Dow visit, and; (4) the long-standing tradition of student-faculty-staff cooperation, albeit strained upon occasion, held firm and all parties fully cooperated in the final showdown.

The events of the remainder of the year and the summer of 1968 certainly did little to ease the mounting tensions and frustrations felt not only by students but by thoughtful people everywhere. The assassinations of Martin Luther King and Robert F. Kennedy, the continued escalation of the Vietnam war, the campaign of Eugene McCarthy, the tragic events surrounding the Democratic convention in Chicago, George Wallace's display of strength, the failure of either major candidate to speak concretely on what students felt to be the burning issues of the campaign, the tremendous increase of racial and urban problems — all of these influenced students particularly.

Since protest, as evidenced during the Dow visit, had not achieved a significant result, or at least had not achieved a significant result within a short time, student activists sought new targets. The Selective Service became the next major target of protest. Such organizations as Resist, which was hardly more than a discussion topic at M.I.T. last spring, gathered considerable strength. In the eyes of many students, this was an opportunity to combine the immediacy of their own personal involvement with the desire to have some definite and observable influence on the "establishment."

Early last fall in New England, Resist sponsored several sanctuaries, where an AWOL serviceman entered a religious edifice and was surrounded by as many anti-draft sympathizers as possible. Community discussions, movies, and formulation of position papers took place. TV and other news coverage was actively sought. A "bust" by Federal or other police authorities, with good news coverage, was hoped for. Although the sympathizers usually pledged themselves to non-violent obstruction, some probably hoped for some evidence of police brutality. Non-violent obstruction usually meant the formation of a sea of human bodies around the AWOL, each body of which would go limp when police hands were applied.

Some of our students and staff had participated in the Boston University sanctuary and the Harvard Theological School Sanctuary, both held early last fall, and at the time, it was assumed that any sanctuary at M.I.T.

would probably take place in our Chapel. We also presumed that the general procedure would be to notify appropriate Federal authorities when the sanctuary first took place, and to take M.I.T. action only to prevent violence until such time as Federal officer or other police arrived to remove any AWOL serviceman who might be involved.

M.I.T. Resist simply introduced a new element, by planning their sanctuary in the Student Center, not in a religious building, and particularly not in our small Chapel.

M.I.T. Resist had reserved the Sala de Puerto Rico through normal channels for the evening of Tuesday, October 29, for a "Greater Boston Pre-Election Teach-in." A few days before October 28, they asked for and received permission to use the Sala on the afternoon of October 29 to "hang posters" and otherwise generally to prepare for the evening session. About noon on October 29, flyers were distributed, announcing that a sanctuary would take place in the Sala de Puerto Rico beginning at noon. By the time I reached the Sala shortly thereafter, some 200 to 300 people had already congregated.

The police authority was notified, and we began to consider what administrative action would be appropriate. We were not yet certain the claimed AWOL soldier was in fact AWOL. In addition, the schedule of the Sala was surprisingly free, with commitments made only to comparatively small groups so that the JP Committee might be permitted to decorate for the Junior Prom scheduled for November 8. Finally, the Sala de Puerto Rico is an important room of the Stratton Student Center, a student building.

I for one did not know what would be the consensus of the student body on this issue. Thus, if we were to follow the policy of the preceding Dow incident, permitting dissent against national policy, provided it was nonviolent and did not interfere with other ongoing activities, an immediate police or other disciplinary move was unwarranted. Based upon President Johnson's policy statement issued at the time of the Dow incident, I issued a policy statement the next morning, Wednesday, October 30, in which I said, in part:

In the present instance, M.I.T., on the one hand, recognizes and wishes to protect the rights of members of our community to express their strong convictions concerning the Vietnam War and the draft. On the other hand, M.I.T. will not intervene in the discharge by civil authorities of their responsibilities toward an AWOL serviceman who is not affiliated with M.I.T., but who is presently seeking sanctuary on our premises.

We recognize that violent actions may result. But, as we have in the past, we rely upon all members of the M.I.T. community to prevent such incidents. I understand that a significant number of those present at the Sanctuary are not affiliated with the Institute. We expect that they too will respect the spirit and integrity of the community in the midst of which they have placed themselves.

By this time, the population of the Sala had grown enormously. My estimate was 20% M.I.T., 70% other Boston area colleges, and 10% miscellaneous. Many of the staff spent the entire day attempting to assess the feelings of the M.I.T. community and to make some projection of what would be appropriate action. In short, the scale of the operation had grown an order of magnitude from that at the start and, although there were a few tense moments, there had not been any violence or obstruction.

On Thursday afternoon, October 31, I called a joint meeting of the Institute Committee and the Graduate Student Council, a meeting at which some Resist members and JP Committee members were also present. This was, to me, a remarkable session. Although the first hour or two was devoted to what I would term an expedient discussion ("We can't get them out of there anyway, why pass resolutions to this effect?"), as time went on, a discussion developed based upon principle rather than expediency. The group's feeling seemed to center around the following points. They disapproved completely of the take-over techniques, and the interference with such scheduled items as the Foreign Language Luncheon and JP decoration, but, on principle, they felt the issue to which the sanctuary was attempting to address itself was of such over-riding importance that it should be permitted to continue.

As the weekend approached, it became increasingly obvious that the large-scale "bust" was not going to come. Apparently, law enforcement authorities were not about to initiate the risk of violence and of the adverse publicity which very well might result from their moving in. It was also obvious that the 24-hour-a-day vigil of those in the sanctuary was taking its toll on those running the sanctuary. These students must have been searching for a way out without letting "the administration" know of this.

Although the attendance, mostly from Greater Boston, was at a high over the weekend of November 3 and 4, the leaders, knowing it would fall on Monday and gradually disappear, sought new phases. They finally decided to move to the student activity floor of the Student Center (the JP could then move into the Sala; the expected fewer members of the sanctuary could be accommodated in the activity lounge; it was a change of scene for the "stir-crazy," etc.).

There was much discussion of holding classes in the sanctuary, and a few were, and of having the AWOL soldier then go to classes in the main building. Without going into the details of all of these arguments, I believe the pertinent policy is contained in an announcement issued by the Provost on November 6 which stated:



Jack Michael O'Conner has no official status at M.I.T. He is a presumed AWOL soldier brought by a student group to the Student Center, in student activity space. As long as the group of students continue to maintain a mode of conduct acceptable to the Institute, the problem that he and the students face is one with the civil authorities. He is not a lecturer and not a student. A professor who chooses to invite him to class informally, does so on his own judgment.

The group attending the sanctuary became smaller and smaller as time wore on. JP went on, although the Committee had to work overly long and hard in preparation, on Friday, November 8. The Alumni Seminar used the Sala on Saturday, November 9. During all this time, a small group of tired students, a few hippies, and several motorcyclists protected the AWOL in the same building. About 7 a.m., Sunday, November 10, police took the AWOL soldier peacefully from among the 10 or so friends who were left.

The restless, unsettled mood of many students was reflected in their concern for campus issues as well as for national issues. Beginning during the spring term 1968 and extending into the opening of this past fall term, undergraduate dissatisfaction with the Institute Committee became increasingly evident. Undergraduates appeared to be either disinterested or negative toward the "irrelevance" of InsComm, and many members of InsComm also were extremely dissatisfied.

A series of investigations and reports on the structure and purpose of InsComm was climaxed by a narrow defeated motion to dissolve the Institute Committee on October 17. The Undergraduate Association President, Maria Kivisild '69, and the Senior Class President, Mark Mathis '69, walked out upon the defeat of this motion. This action seemed to mark the final deathknell for this traditional undergraduate government. As a governing body, InsComm remained largely inactive for the remainder of the fall term, meeting only sporadically and with little apparent continuity of concern. The various subcommittees of InsComm and other student activities continued to function with little apparent regard for the inactivity of the parent body.

The major criticism of InsComm appeared to focus upon the representativeness or nonrepresentativeness of its structure. With the exception of a few officers of this body, all were *ex-officio*, officers elected by living groups, class officers, etc. Thus the criticism was leveled that the individuals involved, while they might have expertise in a limited field, for example, the president of an Institute House might know how to lead his house, they did not have expertise in all-campus matters and, in fact, tended usually to act as lobbyists for their own provincial concerns. Traditionally more concerned with oncampus residence, student activities, and social events, InsComm seemed unable to provide a leadership role in those areas of increasingly important concern to students — the

academic or primary educational business of the Institute, and social and political action off-campus.

The design of new constitutions and structures for undergraduate student government was of considerable interest to many students during fall term and until the early part of spring term. Proposals ranged all the way from those which provided for only minor changes in the traditional InsComm set-up to TANG (Toward a New Government) which called for a complete participatory democracy with a very loose structure. As one might expect, those students who were most interested in the sanctuary were also those students most interested in seeing TANG adopted.

When the oft-postponed student government elections were finally held on March 13, the undergraduates voted a new student government constitution (dubbed "HAC" after the authors Peter Q. Harris '69, Carson Agnew '69, and Steve Carhart '70) which established a General Assembly, composed of students elected from living groups upon an approximate proportional representation basis, and presided over by the Undergraduate Association President, elected by popular vote. In the same election and by a very close vote, Michael Albert '69, who had been one of the leaders of Resist and other student action groups, was elected president. He selected Richard Prather '72 as vice president and Karen Wattel '70 as Secretary General.

Although those accustomed to the rather dry and deliberate "structured" meetings of the old InsComm may have been somewhat abashed by the rather loose and free-wheeling character of the few meetings of the General Assembly which followed, they certainly cannot claim there was not a representation of most student points of view. It is probably still too early to predict whether this large group will be able to coalesce into an effective action structure, distinct from a forum of exchange of information and points of view. Deans Jay C. Hammerness and Robert J. Holden also report their assessment of these changes in their report which follows.

In addition to searching for means to influence student government toward more relevant concerns, students sought, in many ways over the year, to find the means to exert greater influences on faculty and administration, both to change on-campus policies and procedures (curricular and advisory structure reform) and to change the role of the Institute in national affairs (for example, with regard to "war-related" research).

Although the trend toward increasing student membership on various committees of the Institute accelerated during 1967-68, attendance at faculty meetings remained a privilege reserved for members of the faculty. Late in the fall of 1968, the students, led largely by those students

who had assumed leadership roles in the sanctuary, began a more intense attack on the "secrecy" of faculty meetings. Numerous discussions of this matter took place, and an open community forum on the issue of open-closed meetings was scheduled for November 22, under the leadership of Professor Walter A. Rosenblith, Chairman of the Faculty.

At the regular faculty meeting on November 20, a significant number of students declined to respond to the requests of the assistant secretary of the faculty and others to leave before the meeting was called to order. They did, however, leave after President Johnson requested them to do so. He said, in part:

We should all be interested in making student views known and, more importantly, their influence felt. The Faculty will want to discuss this and find further ways to achieve better interchange with the students. I am strongly for this. . . .

In short, I believe we should be prepared to examine every policy, every view, every practice in which M.I.T. is engaged. . . .

But this should be done in a rational manner. This is an Institute that proceeds by discussion — where the good ideas that serve all in this community survive. It is not a place where action should take place by one group coercing another.

Although the sanctuary had been allowed to run its course, the sit-in at the faculty meeting was another matter. The sanctuary had been approved by the student government for the Student Center, and although there were some considerable inconveniences, the abuse of rights of others which occurred was peripheral (for example, "liberation" of the ladies' rest rooms which properly caused some lady employees to be very upset). Uninvited student presence at a scheduled faculty meeting seemed to form a much higher level of interference of rights. Further, the form of protest typified by the sanctuary emerged because we had not yet found the ways nationally to debate and respond satisfactorily to young people who raised the issue. In the matter of M.I.T. student attendance at an M.I.T. faculty meeting, we felt we did have the proper channels through which debate and decision making could take place without such coercive tactics as sit-ins.

During midwinter, several open forums were held on a whole series of issues ranging from modification of curricular requirements to student participation in faculty meetings. There were, by then, student members on a large number of committees of staff and faculty.

At the regular January meeting, the faculty voted to experiment for the remainder of the academic year to permit nonfaculty (mostly students but other staff as well) (1) to attend on a first-come, first-served, limited-seating basis (nonspeaking and nonvoting) and (2) to attend upon invitation of committee or task force chairmen with the right to speak but not to vote. Subsequent meetings of the faculty were characterized by high attendance (of both faculty and nonfaculty) and a quality of

excitement which had been a rarity under the older format. An ad hoc committee chaired by Professor Charles A. Myers is engaged in assessing these and other issues raised by the experimental nonfaculty attendance at these meetings, in order that they may recommend appropriate action to the faculty in the fall.

Given their view of their relative inability to influence Federal decision making, it is not surprising that the attention of many student (and staff) activist groups turned toward their own home institution as being (1) of a scale on which they might have some influence and (2) of national importance and, hence, influential on such larger-scale organizations as portions of the Federal government. During midwinter, such efforts began to coalesce in the direction of attacking the contributions made by several Institute research programs and laboratories to war-related research. Emphasis was placed on the importance of conversion of these research teams "from military technology towards the solution of urgent environmental and social problems." A group of students, primarily at the graduate level, organized the Science Action Coordinating Committee (SACC). They took the initiative in early February to call for a day-long research stoppage as a symbolic gesture both at M.I.T. and at a number of other research-educational institutions.

As this idea gathered momentum, a group of M.I.T. staff members organized the Union of Concerned Scientists (UCS) which, sometimes in cooperation with SACC and sometimes not, planned a research halt at M.I.T. for March 4.

As that date drew closer, opposition and confusion began to mount. After considerable further debate, a program was sponsored by both SACC and UCS, but official recognition in the form of cancellation of classes or other scheduled activities was not granted by the Institute. That portion of the March 4 activities sponsored by the UCS began with a panel on "The Responsibilities of Intellectuals" on the evening of March 3 and continued throughout March 4 with a series of panel discussions and individual speakers on such topics as "Re-conversion and Non-Military Research Opportunities," and "Arms Control, Disarmament, and National Security." The portion of the activities sponsored by SACC on the afternoon of March 4 was highlighted by the presentation of a now famous address by the Nobel Laureate, Professor George Wald of Harvard, and by the public presentation of SACC's demands of M.I.T.

The latter included: (1) the replacement of war-related research with socially constructive work, both on campus and at the special labs; (2) termination of co-op programs with companies extensively involved in war-related research; (3) establishment of a board to help find jobs for students, faculty and staff in nonmilitary areas; (4) termination of credit

for classified theses or courses; (5) abolition of ROTC; and (6) establishment of a single research contract between M.I.T. and the government, in order to remove Department of Defense pressures on researchers.

Campus reaction to the event was highly varied. *The Tech* headline stated "March 4 Activities fill Kresge but Research Goes on as Usual," while *The Catalyst*, the Graduate Student Council newsletter observed:

Because neither students nor faculty have ever been taught very much about communicating with a group or person-to-person, the decision-making sessions of both SACC and UCS were very frustrating and largely unproductive. The SACC leaders tried to discuss their proposals in Kresge, with two microphones servicing the several hundred people in the audience. . . .

However, the members of SACC and UCS are trying to poke through the issues, to investigate and perform rudimentary analysis of the value issues underlying the whole future of technology. They are engaged in an educational and research function which the Institute should have initiated long ago.

During the spring term, SACC developed into the organized student group which provided the major focus of student protest. A considerable amount of research was carried on to investigate professional histories of individual staff members, details of defense-related research projects, and so forth. Newsletters, pamphlets, and placards carried the results of this research, some of it accurate, much of it inaccurate, and essentially all of it slanted toward the thinking of the SACC leadership.

Picketing of the Instrumentation Laboratory and of the main entrance to the Institute at 77 Massachusetts Avenue and rallies on the Student Center plaza became those vehicles through which SACC sought to publicize its demands that research at the Special Laboratories on tactical and strategic weapons be discontinued. Dr. C. Stark Draper, Director of the Instrumentation Laboratory, Professor Rene H. Miller, head of the Department of Aeronautics and Astronautics, and other staff members engaged in several public debates with members of SACC upon these occasions.

By the middle of spring, it became clear that the majority of the M.I.T. community, although in sympathy with the validity of the questions posed by SACC, did not support either the methods used by SACC to air these questions or the implied or specific prejudgments on the questions put forth by SACC.

SACC began to move toward less orderly, almost disruptive, kinds of tactics. A sit-in in the corridor outside the President's Office, while technically nonobstructive since free passage of individuals was permitted, skirted close to disruption by sheer volume of noise and crowding. After some debate as to a suitable location in which to confront President Johnson with their demands, the group finally moved to 10-250. Here, observed by many additional student and staff observers, including Dr.

Draper, leaders of the group discussed a series of demands with President Johnson and Dr. Killian. Although still peaceful, much of the verbiage during this confrontation required a display of extraordinary stamina and patience on the part of these two gentlemen, as well as other members of the M.I.T. community.

On April 28, President Johnson called a special meeting of the Faculty and Administrative Councils to announce his appointment of a review panel on the Special Laboratories. Concurrently, SACC conducted a sit-in outside the President's office but later, upon invitation, attended the final portion of the special meeting. Although the content of the ensuing discussions was similar to that which had taken place at the earlier confrontation, the tone was considerably less aggressive.

During May and early June, SACC concentrated efforts on rallies to oppose Project CAM and generally kept very much before the community the positions SACC members had already developed with respect to many of those issues under consideration by the review panel. SACC's reaction to the first report of this panel at the end of May was mixed, but generally negative. Such words as "whitewash," and harsher terms, were used by some members to characterize their views of the panel's first conclusions.

In an effort further to present their views, SACC chose Alumni Homecoming Day, June 16, as a time to invite to a rally on the Kresge Plaza numerous anti-war and anti-establishment groups, ranging from the American Society of Friends to the Black Panthers, to protest before Governors Ferré of Puerto Rico and Sargent of Massachusetts (both M.I.T. alumni) and generally to protest the make-up and content of the scheduled alumni day panel on "The Human Purpose." Although in the past political action and social action groups on campus had been addressed by either members of the M.I.T. community or those not affiliated with M.I.T., it had been a tacit ground rule which limited the make-up of rally audiences to the M.I.T. community. Thus, the invitation extended by SACC, to potentially large numbers of individuals having no affiliation with M.I.T. to attend the alumni day rally, seemed to add an increased potential for difficulty.

A comparatively small number of persons not affiliated with M.I.T. actually attended the rally. Toward the close of the rally, Gregory Smith '30, past president of the Alumni Association and present chairman of the Corporation Visiting Committee on Student Affairs and member of the review panel on the special laboratories, informed SACC leadership that several alumni together with President Johnson and Dr. Wiesner and other administrative officers would be willing to meet with them in Kresge. A misunderstanding resulted in an attempt by some 30 to 50 of the pro-

testers (mostly people not affiliated with M.I.T.) to gain entrance to the Rockwell Cage in which the alumni seminar was taking place, although no force was displayed. After about one hour of sit-in argument outside the entrance to the Cage, the group agreed to move to Kresge Auditorium. There followed a give-and-take session, in which little mutual understanding seemed to take place. After this large meeting was halted, heated exchanges among several small groups of alumni and dissidents seemed to achieve, in some cases, a degree of constructive communication.

Although some of the incidents, upon which I have reported above, came close to disruption of an ongoing academic or other official activity, in each case we seemed to be able to move away from the brink just before going over. Unfortunately, this was not the case upon the occasion of a visit by Walt W. Rostow on April 11. Professor Rostow had originally been invited by Professor Max F. Millikan to participate in seminar sessions primarily designed for staff and students of the Department of Political Science. In response to a generally expressed community interest to hear Professor Rostow and to question and perhaps debate with him, plans were changed to permit Professor Rostow to speak and participate in a question and answer panel session at Kresge Auditorium.

Although both Professor Rostow and Dean Robert L. Bishop, who chaired this session, attempted to quiet several hecklers in the Kresge audience, they were unable to do so. There were approximately a dozen very active hecklers, and another two dozen or so sympathetic hecklers. The vast majority of the audience of 400 or more clearly disapproved of the heckling. Finally, it became necessary for Professor Rostow to leave, making it impossible for those who wished to do so to hear all of his remarks or to question him or to comment upon his remarks in the question session which had been scheduled.

Those of us who were present during this event and who had the responsibility of making an on-the-spot decision, decided not to try to remove such a large group of hecklers because we were concerned that we not provoke physical violence. In retrospect, this negative decision probably brought very positive results for responsible community self-governance at M.I.T. Reactions which ranged from petitions to editorials was immediate. Overwhelming abhorrence of the infringement upon the personal right to free expression was essentially unanimous. I doubt that we could have achieved this deeply felt agreement had we taken police or other control action at the time.

Toward the middle of April, it became clear that many members of this community were so deeply interested in so many issues confronting us that the normal channels of communication were practically jammed and the normal decision-making processes were overloaded — perhaps ap-

proaching serious breakdowns. We recognized the need to develop both an increased sense of community and of mutual understanding of the range of major issues which faced M.I.T. Additionally, we recognized an increased involvement of all segments of the M.I.T. community in identification of issues as we began to think through them.

Most of the mechanisms which had earlier been proposed to solve these problems, such as halting classes for a "Day of Concern," seemed to suffer from the pitfalls characterized by one of our resident tutors who wrote the following to me:

As an observer of the general undergraduate scene, by virtue of my residence in an undergraduate living group and as a teaching assistant, I would like to pass on a brief note of caution. I think that the events of the past weeks and in particular several attempts at dialogue have not in any way dispelled existing misconceptions, but rather have tended to further confuse the thinking of many on this campus, especially at the graduate and undergraduate levels. Seminars and open meetings addressed to 'when did you stop beating your wife' type questions produce very few positive results. If anything, participation in them tends to legitimize all the issues raised, real and imagined.

Before proceeding on any 'Day of Concern' I respectfully urge that *careful* examination be made of the topics to be discussed. There are abundant appropriate subjects for careful inquiry. . .

Although the topic which had been placed on "the front burner" in the spring was "war-related research" and although ROTC was coming close to a boil on a back burner, it was imperative that these and similar issues, such as programs for the disadvantaged, academic and curricular reforms, and relationships with the surrounding community, be discussed within the context of a far broader framework, that of the appropriate role of M.I.T. in our present society. It was also necessary that they be discussed with some recognition of and understanding of the pluralistic nature of the policy formulation and implementing structure at this institution. Further, it was imperative that we pay very careful attention to the need to develop vehicles for discussion which would permit and encourage all points of view to be represented. Finally, we had to develop a plan which was both open-ended and within the system. That is, we could not expect within a few days or a few weeks to have all the answers, so that proposed solutions on all matters could be put to a vote. However, we could see to it that the views which resulted from such discussions be fed into existing committees, other duly constituted groups, and/or appropriate Institute officers.

At a special faculty meeting on April 28, the faculty approved the appointment of a special student-staff Arrangements Committee "to establish additional avenues through which members of the M.I.T. community may exchange views and ideas on a broad range of issues of common concern." The faculty authorized the cancellation of classes up to the equiva-



lent of one full day in order to encourage broad participation in this community effort during the remainder of the spring term.

The Arrangements Committee, chaired by Professor Walter Rosenblith, Chairman of the Faculty, achieved a remarkable degree of cooperation and support from all parts of the M.I.T. community. "Agenda Days," as the program was called to signify the intent of the faculty that ideas and suggestions would become serious items for later consideration and possible implementation, began with dinner-evening discussions in living groups on May 6. Classes were cancelled from 1 to 5 p.m. May 7 to permit all to attend a brief "kick-off" convocation at which President Johnson spoke, followed by discussions organized and hosted by the various academic departments. From 8 to 10 p.m. that evening, WGBH aired a live television panel with M.I.T. panelists on "Issues and Choices Facing Universities." Living groups again hosted discussion groups. On Thursday, May 8, classes were cancelled from 2 to 5 p.m. to permit all to attend discussions arranged on a topical basis over a broad range of internal and external issues.

At this writing, the reports from the various group discussions are being analyzed. Ideas and suggestions are being categorized and distributed to appropriate committees and to faculty and administrative officers. An interim report prepared by Prof. Edgar H. Schein and Stephen H. Kaiser, G, II, was published in *The Tech* on May 23. The following are extracted from that report:

The ideas and suggestions can best be grouped in terms of the basic categories used for the topical discussions: (1) relations between M.I.T. and the defense establishment; (2) relations between M.I.T. and the society around it; and (3) internal relations and needs within M.I.T. . . .

Many groups grappled with the role of the university in society, identifying at least three such roles: the development of knowledge through research and scholarship, the transmission of knowledge through teaching, and application of technology or science to society and the community. There seems to be a growing feeling that a fourth role is emerging, that of articulate critic of society. . . .

Several groups agreed that M.I.T. needs to provide much better *guidance* and advice to students concerning how M.I.T. really works and how one can effectively plan one's educational path through it. One might provide an intellectual ombudsman or consultant, or write a good educational 'guide book,' or provide better training for advisors to insure that they know how and where to find the answers. . . .

In many of the departmental meetings it was revealed that students want a closer relationship with each other, with graduate students, and with their faculty.

A closely related issue which was covered in many groups concerned the students' role in the *governance* of M.I.T. It was proposed that students might have a greater voice in departmental matters. . . .

On a broader scale, it was suggested that one might consider permanent student representation on all departmental, school, university, and corporation governing bodies. . . .

Several suggestions dealt with the curriculum. . . .

Finally, most groups who reported felt very positive about Agenda Days because of the amount of communication and exploration of issues which they

facilitated. Many groups suggested setting apart regular times during each semester for such discussions, and some groups suggested procedures for polling the groups and arriving at community consensus on important issues. . . .

Necessarily the foregoing comments can be neither a complete summary of those events at M.I.T. which took place during this last academic year and which fall under the broad category "unrest," nor can these comments be taken as a completely balanced and accurate interpretation of what actually took place at any one event or, in a more subtle way, what were the motives, which forced the involvement of any one person or group of persons. I have prepared the comments from the vast array of memoranda, file documents, and scribbled notes which I have accumulated during this very active year. I intend them in part as a record of the year; I intend them also to provide for the reader who has not been intimately involved on this campus some feeling for the complexity of the issues of concern and of the rising sense of disaffection among our students with our society's goals and structures, indeed a rising sense of frustration at the inability of any one person to influence the vast complex of government and business, or the university, for that matter.

This latter view was most forcibly brought home to me during the first weekend of the sanctuary early last November when I was standing "watch" on the balcony overlooking a sea of sprawling sleepers jammed in on the huge floor of the Sala below. The place was quiet and rather eerie. Suddenly an alarm (which later turned out to be a false report) that the "Feds" were coming was flashed in from one lookout. The entire group was immediately awakened and instructed to take their "non-violent resistance" positions. There they were, many more than 1000 young people, jammed in, kneeling down facing the AWOL soldier, waiting to be busted, and a single amplified voice gave the instructions "easy now; remember not to obstruct, just go limp." I couldn't help but feel terribly moved, not by this method of protest to which I frankly admit a personal abhorrence, but moved by what I can best describe as the pathetic nature of the whole operation and terribly saddened that we had gotten to such a state of affairs in this country that significant numbers of our young people reacted in this fashion.

When I reviewed this sanctuary experience at the Alumni Council in January, several questions were asked concerning the possibility that the whole affair had been designed and led by a few "outsiders," implying a conspiracy. I could not give answers which I think some expected to hear, that, indeed, a few "subversives" were responsible for this, as well as other incidents of student unrest at M.I.T. Nor are all of the activists characterized by the arrogance and intolerance which afflicts some in these groups. Undoubtedly there are a few such individuals in our

midst or nearby, but they pose problems for the moderates or old-fashioned liberals only because such words as confusion, bewilderment, anger, lack of confidence, and distrust truly characterize the attitudes and outlook of many more of this community than I, for one, like to see.

Repressive action on the part of the university or government to maintain the status quo in whatever the area will not provide the answers in this present state of affairs. Indeed, I feel that only further exacerbation can result from such an approach. Willingness to listen, to be open and candid, to respond, and to share knowledge and responsibility (and hence power), and to provide some "good old fashioned leadership" offer, in my view, the only possible route to a reasonably healthy and evolutionary change for the better. Given some tolerance for human error, I believe it is fair to say this latter route was the intended route of most of M.I.T. during this hectic year.

#### STUDENT RESIDENCE

Last year, the President asked Mr. Philip Stoddard, vice president for operations, to head a task force charged with the responsibility for recommending means by which the Institute might add both to its own housing resources and those of the surrounding communities. With dedicated assistance from many members of the Institute staff, this task force effort moved ahead this year on the development of several ambitious programs. On April 9, President Johnson and Dr. Killian announced a major housing plan which could provide up to 1600 new housing units, off-campus in Cambridge, available to a broad spectrum of families and individuals. In addition, a plan to provide accommodations for approximately 800 on campus was set forth. The off-campus program is described elsewhere in this report. I shall focus attention here on the on-campus program.

MacGregor House, the first of the "new breed" of Institute Houses for undergraduates is expected to be completed in time for September 1970 occupancy. It will house 324 single students in single rooms arranged in suites. The suites will be arranged in nine entries, in each of which there will be provision for a resident graduate tutor. The entries will be grouped to form the house with house commons, dining rooms and similar amenities. A resident senior tutor and housemaster and their families will reside in the house under the Institute's housemaster-tutor residency program.

With MacGregor House available, Burton-Conner will be closed for a complete renovation. The present capacity of 542 will be reduced to approximately 350 in order that the program and the quality of environment in this house may be brought to the standard set in MacGregor House. To permit this building to be vacated during the remodeling process, a majority of the residents will be transferred to MacGregor

House. We plan to accommodate the remaining 200 or so men in apartment blocs located outside Cambridge. Re-occupancy of Burton-Conner is expected in late 1971.

The Burton-Conner program and planning is now in the working drawing stage. Much credit for the quality of this effort should be given to the "Client Team," which was chaired by Mr. Laurence H. Bishoff, director of housing and dining, and which included student and faculty residents of Burton-Conner and the architects, Mr. and Mrs. Marvin Goody, of Goody and Clancy, Architects. Not only did this cooperative effort result in a far better design than any one group could have developed, but, in many less tangible ways, this team demonstrated the validity of student-staff joint effort.

At this writing, we have just reached an agreement with The Architects Collaborative to undertake the design of the second new West Campus House, to be located on Memorial Drive just west of MacGregor House. The program for this house will represent only minor departures, dictated primarily by the need for greater economies in these inflationary times, from that of MacGregor. Although funding is not completely determined, we hope to be able to occupy this new undergraduate house in three years, or four at a maximum.

Presently, we are in the final preliminary design stages of a new graduate student residence, presently called Westgate II, and sited adjacent to and just south of the present Westgate married student complex. We hope in this program to develop apartment configurations which will permit occupancy by varying proportions of single graduate students and married students with only minor structural changes required as the occupancy shifts. At first, we anticipate that the building will be occupied by groups of single graduate students, since the relatively high rental charges for each apartment will most easily be met by a group of single students, rather than by a married student family. In addition, it is groups of single students who seem to be willing and/or able to pay the rapidly escalating rentals in the surrounding community and who are thus parties to the plight of the poorer families competing for the same housing.

The rental costs result because there is little or no gift capital available for the project. Thus, present-day high construction costs must be amortized through rental income. As construction costs continue to rise with time, we anticipate that married students will reach an income level which will permit them to occupy some fraction of the Westgate II apartments. Thus, for economic reasons, as well as for what we believe to be desirable social-living conditions inherent in a "mix" of single and married students in a graduate residential structure, the long-term use of Westgate II will be to house both.

The four projects outlined above represent massive and important additions, both in numbers of accommodations and in the quality of these accommodations, to our on-campus housing program. There remain, however, many problems to be resolved. Although tentatively we plan to convert Bexley Hall and Random Hall to graduate student occupancy, when the second new West Campus House becomes available to house those undergraduates presently residing in these two old "temporary houses," this decision is not firm. Further, these houses, particularly Bexley, will require extensive upgrading if we are to continue to house students, graduate or undergraduate, therein. The futures of the East Campus parallels and Senior House are also not too clear, particularly if the East Campus buildings and/or site is taken for academic and research expansion. Finally, both Senior House and Ashdown House are sorely in need of considerable renovation and refurbishing. In short, we have now made a first-rate start, but we have a considerable distance to travel to provide on-campus residential facilities of a quality and character consistent with our academic program.

The Fraternities Collaborative is a cooperative undergraduate-alumni effort to explore the feasibility of constructing new fraternity houses for the five member fraternities, Alpha Tau Omega, Kappa Sigma, Phi Sigma Kappa, Sigma Alpha Epsilon, and Sigma Nu. This Collaborative has submitted to President Johnson a "Design Program for a New Fraternity Complex," which has the potential of a most exciting undertaking. Not only does this represent the first effort in several decades on the part of our M.I.T. fraternity group to design a structure to meet their program (rather than to adapt their program to an existing structure, as essentially all of those houses located in Back Bay have been forced to do), but it represents the first such multi-house cooperative effort ever at M.I.T. The proposed approach has the promise of achieving the benefits of large scale in design and construction without sacrificing those benefits of individuality and personal scale which are so important to each fraternity.

The primary problems are those of siting and financing. In presenting their report to the president, the Collaborative solicited the Institute's assistance in assembling and making available taxable sites at nominal costs and in finding ways to increase greatly the level of giving to the Independent Residence Development Fund of our Alumni Fund. As we respond, we must keep in mind the strong probability that additional multiple-house groupings will approach the Institute in the near future with similar proposals. Only recently, a new cooperative effort called Comm 8, composed of undergraduates and alumni of Alpha Epsilon Pi, Delta Upsilon, Phi Kappa Sigma, Phi Mu Delta, Sigma Alpha Mu, Sigma

Chi, Sigma Phi Epsilon, and Theta Chi, has been formed to explore problems similar to those faced by the Fraternities Collaborative.

It is my own hope that we will be able to find the mechanisms to respond positively and constructively to the present and similar future requests. Should our independent residences not be able to find the means to meet the challenges posed, on the one hand by the Institute's great efforts to upgrade Institute-owned housing and, on the other hand, by the deterioration of both the physical plants and neighborhoods in which they are located, we shall be faced with even more serious housing problems than we now have. There will be the loss of the accommodations presently provided, but, more importantly, there will be the loss of these important elements of diversity and self-determination which we regard as important to our overall undergraduate housing program.

I do not mean to imply that the decline of our fraternities is practically upon us, nor do I mean to imply that the only problems we and they need cooperatively to resolve are physical plant problems. Indeed, the more fundamental issues now actively under attack by our fraternities are centered on the need of these traditionally conservative social structures to find new ways to respond positively to the rapidly changing living styles and social needs of incoming students. The old problems of finding the balance between rights and freedom of the individual and the limitations upon these rights and freedoms necessary for the health and continuity of the social grouping seem to require careful reevaluation. These problems are not unique to fraternities, but they are certainly of greater importance to these groups than they are, for example, to dormitory groups, because the fraternities have traditionally relied upon a greater degree of personal commitment to the social grouping. The primary reason I feel optimistic concerning our fraternities' future lies in their present willingness to identify these issues cooperatively and to seek solutions in a more open fashion.

Although the growth in our fraternity population has kept pace roughly with the slow growth in the size of the undergraduate male population (each year about one-third of the undergraduate men are affiliated with fraternities) the number of chapters (27 chapters of "nationals" and one "local") has remained constant for a long period. In recognition of this continued population pressure, the IFC this past year relaxed its colonization rules. A small group of undergraduates who wished to start a new fraternity worked closely with officers of the IFC (Interfraternity Conference) and the dean's office to explore colonization by several national fraternities. As a result, a "colony" of Pi Kappa Alpha has been established and, at this writing, the undergraduates affiliated with this colony,

alumni in this area, and members of the Institute staff are actively seeking a home for PKA in September 1969.

A new cooperative effort among the Freshman Advisory Council, the Campus Housing Office, the Dean's Office and, particularly, the Interfraternity Conference and the Dormitory Council resulted in a new high in attendance at the Rush Week preceding Freshman Orientation last September. Over 800 new men attended and some 373 pledged fraternities by the close of Rush Week, a new all-time record. Of far greater importance than the numerical statistics was the vast improvement in attitude and relationships evident throughout this time period. Although fraternity-Institute House competition continued, the primary focus of almost all participating upperclassmen was clearly on the well-being of the incoming freshmen.

A new room assignment scheme for the men's Institute Houses was also implemented for the first time. Those freshmen who moved into Institute Houses were assigned by the Campus Housing office only to the House; the student room committee of the individual houses then made the actual room assignments and later arranged the changes to meet individual preferences as nearly as possible. The resulting "coefficient of satisfaction," despite the generally poor physical quality of the accommodations available to freshmen, seemed to be considerably higher than we had been able to achieve in the past when centralized room assignment control was exercised.

Our positive experience with these changes, together with other considerations of freshman orientation, have resulted in the design of a completely new format for rush-residence selection and orientation for next September. These are reported by Mr. Peter Büttner in a subsequent section.

The move to student control of accommodations within the Institute Houses represented another step in our continuing efforts to foster greater student participation and responsibility in the residential programs. With the exception of certain rules governing eligibility for occupancy, periods of occupancy, safety, and financial matters, the only "centralized rules" governing student life in the undergraduate residences which remained following this step in room assignment control were our "parietal" rules.

During the academic year 1967-68, several efforts on the part of student leaders were made to liberalize still further those rules which had been arrived at by consensus a short time ago. None of these efforts was carried to the point of decision making, although during the past year, the Dormcom and IFC cooperated with the dean's office in undertaking a thorough review. As a result, the Executive Committee of the Corporation, on March 6, approved a joint recommendation from these students,

the dean's staff, the chairman of the Faculty Committee on Student Environment, the Academic Council, and the Corporation Visiting Committee on Student Affairs that the formulation and administration of parietal rules in each of the recognized undergraduate residences be delegated to the undergraduate governing body in each of the residences. In the case of the fraternities and the M.I.T. Student House, the approval of the appropriate alumni-owning corporations was to be required.

In support of this move, I argued, in part:

While past arguments for the establishment and enforcement of parietal rules have been many, most seemed to hold that parietal rules formed vehicles through which the university could both discharge a kind of *in loco parentis* responsibility and also state, or at least imply, some standard of morality.

Given that the Institute has purposely moved within the last several years toward decentralization of residential rule-making and enforcement, as part of a deliberate policy of developing all possible vehicles to encourage individual and group responsibility, and of encouraging the development of ability to deal with 'gray-area' decisions, undergraduate students view the 'centralized specification' of parietal rules as incongruous. . . .

If we can turn over this last social rule establishment task to each living group, I believe we will then be in a far better position to establish a quality of relationship which will enable such questions as ethics, morality, taste, etc., to be addressed more openly and constructively than presently appears possible. With the house-master-tutor program now fully accepted and supported, we have additional resources . . . to bring to bear on this task. . . .

As a necessary procedure under this new policy, each living group was required to inform the dean's office of its own rules and procedures, and all recognized living groups complied. I believe it is fair to say that very positive gains were made in delegating these responsibilities. Certainly a significantly greater awareness of and appreciation for the complexities of such social issues characterized the attitude of student governing groups as they came to grips with these matters.

In a section which follows, Dean Emily L. Wick reports the considerations our undergraduate women have given to the new policy as well as to a new on-campus housing requirement for the coeds.

Although undergraduate coeducational housing has become almost commonplace on many campuses, there has been comparatively little pressure from students or others to make this move at M.I.T. My personal position has been not to support the development of one or more coeducational Institute Houses, until such time as there were a sufficient number of undergraduate women at M.I.T. to permit us to provide both a segregated women's residence (McCormick Hall), as well as one or more coeducational residences. In this way, both the undergraduate women and men would have the flexibility of choice, so that each might decide whether or not he or she wished to live in a coed residence.

Our fraternities have not given truly serious consideration to this



matter, but the M.I.T. Student House, our only cooperative undergraduate residence, has done so. This independent undergraduate residential group, by careful study and argument, has developed a serious plan for coeducational living which they hope to put into effect next September. The undergraduates involved worked closely with their own alumni-owning corporation, members of the dean's staff, and others during their discussion and planning processes. Should this experiment prove successful (and all indications point toward success at this time) this independent cooperative group should provide an important element of choice and diversity in residence, particularly for our undergraduate women.

The Institute has long recognized the importance of providing good food services for students, not only for reasons of physical health but for the encouragement of pleasant enjoyable living and social environment as well. The definitions of what constitutes "good" food services probably number as many as the students and staff involved with these services. Quality, quantity, flavor, visual attractiveness, variety, and so forth, are all subjective matters. Each is discussed and "demanded" by many or all, provided, of course, that the costs are minimal and kept constant, regardless of what happens to the wholesale food price index or in the union negotiations with management. The most critical test of our success in providing good food service seems to occur in the "Commons Houses" — Burton-Conner, Baker, and McCormick — where each house is provided its own dining room and where residents are required to take "commons," 15 meals per week, unless they are excused for religious or medical reasons.

On the whole, both our commons and a la carte food programs appeared to enjoy a reasonably high standard of acceptability through the academic year 1967-68. In particular, the unlimited seconds policy for commons meals, introduced at the beginning of that year, combined with an imaginative "special events" program appeared to meet the needs of most students. But student dissatisfaction gained during 1968-69 to the point of promulgation of a commons strike around mid-term.

For some time, it was difficult to sort out the underlying causes for the strike. The compulsory aspect of the program, declining quality, poor service, and other complaints were aired extensively. After several weeks, it became evident that, for most students, the issues of quality, service, and responsiveness or flexibility were of controlling importance. Most felt that the sharing of the fixed costs of an individual house dining room by all members of the house, the required participation in the commons program for residents in the commons houses, was a fair and equitable policy if the food service met the other criteria. In fact, a few students availed themselves of a newly offered "club plan" under which each stu-

dent paid a "club fee" approximately equal to a student's proportionate share of the fixed costs of the dining service. Under this plan, students were able to purchase at less than a la carte prices only those meals they wished to take but at the same time they provided their fair share of the fixed costs of providing this service to the house.

Many of the students' complaints regarding quality, service, and flexibility appeared justified, and the dining service undertook to make significant improvements. The threatened boycott was not carried through, except for a few individuals. Some of these latter insisted that the primary issue was not quality or service but the compulsory aspects of commons, and they undertook to conduct a questionnaire survey of commons participants on this question. Although these results were inconclusive, the dining service has initiated an intensive cost study of this issue, hopefully in order to answer definitively a series of questions relating to what would be the fiscal impact on students should we move from the required commons policy.

#### STAFF

Professor Gian-Carlo Rota of the Department of Mathematics served as chairman of the Freshman Advisory Council for this past academic year. Under his able guidance, several new programs in freshman residence selection and orientation and in advisor recruitment and development have been initiated. In view of his other commitments, Professor Rota asked the President to be relieved of this very heavy responsibility before the next academic year. Professor Hale V. Bradt of the Department of Physics is to be chairman of the Council for 1969-70.

When Professor E. Lee Gamble, Professor of Chemistry and Master of Baker House, left on a one-year leave of absence at the beginning of this academic year, Professor Isadore Amdur '30, also of the Department of Chemistry, and Mrs. Amdur agreed to "pinch-hit" for the Gambles. This they have done with enthusiasm, sensitivity and interest. Both "their boys" and we are most appreciative.

Since Dr. Gamble decided to remain for an additional year at the Birla Institute in India, he has concluded that he must resign as Master of Baker House, a post he has held since 1961. We are greatly indebted to the Gambles, for they have contributed in generous measure to the growth of several generations of Baker undergraduates. Professor M. Nafi Toksöz, Associate Professor of Earth and Planetary Sciences, who has served as Senior Tutor at Burton-Conner since 1965, has been appointed to succeed Professor Gamble as Master of Baker House, beginning the next academic year.

Dr. R. Mark Price, Assistant Professor in the Department of Physics,

together with Mrs. Price, will succeed Professor Toksöz as Senior Tutor of Burton-Conner.

Because he has been called to active duty by the Navy, Mr. John G. Kassakian '65, Instructor in the Department of Electrical Engineering, has resigned as Senior Tutor of Baker House. He and Mrs. Kassakian will be succeeded by Professor Richard S. Naylor, Assistant Professor of Earth and Planetary Sciences.

Dr. Larry D. Kirkpatrick will leave the post of Senior Tutor of McCormick Hall at the close of this academic year to move to a new faculty position at the University of Washington. He and Mrs. Kirkpatrick have been succeeded by Mr. and Mrs. John Heine. Mrs. Heine '67 is presently a candidate for the Ph.D. degree in the Department of Biology.

Mr. Kenneth Schoman '67, Assistant to the Dean of Student Affairs since 1967, will become Special Assistant to the Provost for this next year. Several of his responsibilities in the Freshman Advisory Council will be assumed by Mrs. Amy Metcalfe who has been appointed Assistant to the Dean for Student Affairs as well as Undergraduate Selective Service Advisor.

Mrs. Dorothy Bowe and Miss Alice Seelinger were appointed assistants to the Dean for Student Affairs during the academic year. Mrs. Bowe works closely with Dean Wick in our programs for women and the pre-medical advisory program. Miss Seelinger, as Administrative Assistant, will move with me to a new assignment beginning July first.

As I leave the post of Dean of Student Affairs after eight years, to become Vice President, I must again express my sincere appreciation to those many members of the Institute staff, and the many students and alumni with whom I have had the privilege of working throughout this stimulating period.

Like all human organizations, the dean's office has passed through several stages of evolution. The dean of students of the early days became the dean of undergraduates in the late twenties; this office again became the dean of students through the thirties, forties, and fifties, and, finally, the role of dean of student affairs was created, effective with my appointment in 1961. For the next academic year, with the appointment of Dr. Benson R. Snyder as Dean for Institute Relations and Professor J. Daniel Nyhart as Dean for Student Affairs, a further evolution and broadening of concerns are reflected. To these gentlemen, I wish every success and my complete support and cooperation.

As in the past, I have asked several of my associates to report on those areas for which they carry primary responsibilities. Their reports follow.

KENNETH R. WADLEIGH

**THE FRESHMAN YEAR****CURRICULUM**

The trend toward diversity in the freshman year continues, with a further lessening of emphasis on level of preparation in favor of greater focus on content, purpose, and style. Approximately one-fifth of the Class of 1972 elected the new two-term physics sequence designed to be compatible with earlier changes in the general Institute requirements and better serve the needs and interests of those students planning to take only one year of physics. A large number of freshmen chose the newly created subject, Introduction to Solid State Chemistry, and the Committee on Curricula routinely approved petitions from these students permitting them to substitute that subject (or, alternately, one of two offered by the Department of Chemistry) for the traditional chemistry subject specified as one of the General Institute Requirements. During the spring the Faculty approved, along with other changes proposed by the Committee on Educational Policy, a change in the General Institute Requirements, specifically to identify any one of the four (3.091, 5.01, 5.41, or 5.60) as fulfilling the chemistry requirement.

The Department of Mathematics announced that the Class of 1973 will be able to take advantage of a new two-term sequence in calculus which is designed not simply to reflect differences in preparation but also different levels of interest in or potential use for the subject. Thus, next year's freshmen will have three versions of calculus to choose from, ranging in primary emphasis from standard techniques and routine applications, on the one hand, to a rigorous, theoretical version of calculus for those very strongly inclined toward abstract thinking and theoretical work.

There are also planned three special programs for the Class of '73. These are discussed in the report of the Provost.

**ACADEMIC PERFORMANCE**

This year was the first in the four year experiment involving pass-fail grading for all subjects taken by freshmen. In February, the Committee on Evaluation of Freshman Performance presented an interim report to the Committee on Educational Policy. The following is quoted from the introduction of that report:

On balance, freshmen, upperclassmen, advisors and instructors have reacted positively to pass-fail. However, experiences and opinions are not uniformly favorable, and the partial vacuum created by less 'precise' grading has brought other aspects of the educational process into sharper focus.

Before I elaborate on these observations, you should be aware of the tenor of our deliberations on the question of how to evaluate the experiment. The following points were among the conclusions that emerged from frequent and lengthy discussions during the fall:

1. There was a need for a clear statement of the expectations of pass-fail. A sub-committee composed such a statement;
2. Even with broadly stated expectations, the answer to the question 'How is it working,' is complex because of the multitude of likely side effects;
3. More specific questions can be posed than we can possibly answer in four years, much less one; furthermore, we don't pretend to know enough about how to predict the outcome so as to be able to select with any certainty all the 'right' variables to measure;
4. The experiment can hardly be controlled, in the laboratory (scientific) sense of the word;
5. Therefore, both our intermediate and final conclusions will rest largely on qualitative data, much of which will be the judgment of the 'principals,' with a lesser dependence upon 'hard' data, grades and the like.

More significantly, we have come to view freshman pass-fail less as an experiment, the likely outcome of which is uncertain, and more as an integral part of the educational reform characteristic of the Institute today. We have a frank expectation of success, and we foresee our efforts being directed, not simply toward evaluation, but toward reinforcing benefits and correcting weaknesses, in short, toward 'making it work.'

Regarding the latter point, the report concluded, in part, as follows:

Above all, there is a clear requirement for broader understanding, among teachers of freshmen, of the need for:

1. Nearly continuous, easily understood, helpful, diagnostic feedback on performance, to provide both a sense of where the student stands, as well as, a direction for his efforts;
2. A sufficient base of personal contact to support informal summary evaluations. Communicating this requirement and exploring ways to meet these needs effectively will occupy much of our time in the months ahead.

Many of the faculty will be looking to academic performance, both during the freshman year and later, as a measure of relative success or failure of the pass-fail experiment. At first glance this seems to be a natural way to evaluate the experiment. Unfortunately, this route, like all the rest, is lined with many booby traps and must be pursued cautiously. For example, most grading has traditionally been done on the curve, and many subjects, furthermore, are traditionally in a state of flux, causing either different material to be covered or students with different sets of qualifications to take them, or both. And of course the academic qualifications and professional objectives of consecutive freshmen classes continue to change. On top of these factors, some proponents of pass-fail maintain that apparently lower academic performance, per se, particularly in the freshman year, is hardly to be construed as a negative or undesirable effect; the benefits that matter most will appear years later in the form of a greater degree of self direction and an ability and inclination toward continuing self study.

Notwithstanding the difficulties in interpreting "hard" data, some of what we now have is probably relevant. The table below shows the pro-

bation and disqualification figures for the Class of 1972, compared with those of previous years.

Table I Incidence of Probation and Disqualification

Class	Probation in February	Probation in June	Disqualification in June
Average of			
1966-68	51	43	23
1969	35	41	9
1970	35	52	8
1971	28	28	7
1972	28	44	7*

\* In line with a new policy of the Committee on Academic Performance, all but 1 of these was a "negotiated withdrawal," whereby the student was urged to take some time away from M.I.T. before attempting to continue his studies. In several of these cases the students would have been permitted to continue in the fall, on probation, if they had declined to withdraw.

The probation figures, identical at the end of first term, but higher at the end of second term compared to last year, tend to support subjective observations from both students and faculty that academic effort slackened somewhat during the spring term. Again, however, one should be cautious about attributing this apparent shift either necessarily or entirely to pass-fail.

More significant, in my view, are comments (frequently unsolicited) received from both students and their advisors. Most of the negative observations appear, at least in part, to come from those using pass-fail as a scapegoat to cover up their own shortcomings or deficiencies in the general academic process. The favorable comments, from both high and low performers, tend to be expressions of gratitude for the opportunity and inducement to make the most of a difficult but important transitional phase, without the threat of double jeopardy, characteristic of the A-F grading system. A desire to ease transitional pressures factored heavily in the decision to implement the pass-fail experiment, so at least some realization of initial objectives seems to have been achieved.

#### THE FRESHMAN ADVISORY COUNCIL

The 97 freshman advisors, as well as the 20 advisors to undesignated sophomores (this year coordinated by Mr. Richard A. Sorenson), continued to play an increasingly important role vis-a-vis their advisees. Part of this added involvement on the part of freshman advisors came about as a result of the written evaluation process associated with pass-fail, whereby, at the middle and end of each term, written evaluations were completed by each student and his instructor in each subject, the reports making their way back to the students via the advisors. In many cases, the additional information provided by these written evaluations enabled the advisor to take a more directed role in counseling his students.

On an experimental basis, six freshman advisors, offering seminars in

the fall term, were assigned their seminar students as advisees. Indications are that this dual relationship tended to be mutually supportive of both the teaching and advisory functions, and with the support of Professor Edwin R. Gilliland, who heads the Undergraduate Seminar Program, arrangements have been made to add to this aspect of the program next year.

Professor Gilliland's successful efforts to encourage those faculty members offering freshman seminars also to become freshman advisors was one of several factors contributing to the overall strengthening of the F.A.C. (Freshman Advisory Council) for next year. The other two involve the methods by which advisors were recruited and the creation of an entirely new group of associate advisors, the title given to the 80 seniors and young graduate students who will support the efforts of the F.A.C. for the Class of 1973.

In the past, advisor recruitment has been handled almost entirely through department chairmen, who have been asked to designate members of their staff in proportion to the relative size of their teaching faculty. Inevitably, by this procedure, each year a certain number of faculty with no particular interest in freshmen, per se, were "volunteered" for the job. Given the noncredit nature of the task, this situation was never a particularly healthy one. In an attempt to improve matters, Professor Rota, Chairman of the F.A.C., took the first of what will be a continuing series of steps to increase the self-selective nature of the F.A.C. First, all current advisors were asked whether or not they would like to continue in that capacity. Second, several interested students mounted a campaign through *The Tech* to solicit recommendations for advisors from students. Third, committee chairmen and other key faculty members were asked to identify potential freshmen advisors. Those members of the faculty and staff, recommended through steps two and three, were asked whether or not they would like to become freshman advisors. The combined result is essentially an all-volunteer advisory group of nearly 140, up approximately 20 per cent from the departmentally appointed group during this past year.

The associate advisory concept grew out of a recommendation made by several students, and the principle recruitment efforts were conducted by Harold L. Federow '70 and Miss Pamela T. Whitman '70. Miss Whitman will work with the F.A.C. during the coming year as coordinator of the associate advisor effort. At this point, the role of the associate advisors remains largely open for subsequent definition by each associate and the advisor with whom he or she works. Midway through the year, advisors and their associates will be asked to critique the concept and make recommendations concerning the future of the program.

Three other major activities of the office should be mentioned. The first concerns Residence-Orientation Week, the newly created union of Rush Week and Freshman Weekend. A critique of the events of Rush Week and Freshman Weekend, 1968, led all of us to the conclusion that a number of changes were called for. The new program, to be tried for the first time for the Class of 1973, encompasses the rushing activities within the total orientation period. This will extend the time previously available for presentation and consideration of academic information and will increase the number of orientation activities available to students participating in only part of the rush process.

In the area of course orientation, we have made some progress toward the objectives outlined by Professor Paul E. Gray a year ago. Whereas former programs developed by this office were one-time affairs, occurring during late spring, plans have been made to change this to a more continuous process of information transfer, beginning in the fall. An assessment of freshmen needs regarding career counseling led us to the conclusion that the most logical source for this function was the individual department itself. Furthermore, many of the weekly colloquia and seminars conducted at the department level appear well suited to the function of communicating both information and style about a variety of professional fields. We have suggested to the department chairmen that they consider the development of a continuing series of programs of special interest to freshmen and have solicited their help over the coming year in the development of a centralized source of ideas for these kinds of programs.

The past year has seen both a change in the literature actually sent to incoming freshmen and a change in our outlook toward it. Previously, counseling literature has consisted of two booklets, *Academic Information for Freshmen* (sent to the freshmen) and the *F.A.C. Guide* (for advisors only). These seemed to be limited in several ways: since they were bound, they were fixed in content and could not be modified or expanded as inevitable curricular revisions occurred; only the *F.A.C. Guide* contained a thorough directory of helping resources, something of great use to the freshmen themselves; and advisor and student each had different preparation prior to meeting, which left us with the feeling that they were not the colleagues we assumed them to be in this academic enterprise. Accordingly, we have constructed a single volume for both freshmen and their counselors, *The Freshman Handbook*. Looseleaf in format, its structure and flexibility have proven invaluable.

The content of the *Handbook* is purely factual or concerned with the direct interpretation of factual material. It describes the "nuts and bolts" — the corporeal or ephemeral side of the freshman year. In our thinking



about the freshman year and in student feedback on our counseling information, there has been the implication that this approach, though fundamental, is incomplete. There is a need to describe the more theoretical and persistent processes at work over the entire first year, something which might be called "the freshman experience." We have made some progress in identifying the dimensions of this psychological and social experience, and have embarked on some reading and research in an attempt to understand the forces at work. Though the desired end-product is a second book, entirely separate from the annually revised *Handbook*, much remains to be done beyond our initial hypothesizing before such a volume will see completion.

During the coming year, answers need to be sought to two important questions concerning students and the advisory system. The first of these deals with the purpose and structure of the advisory system itself. As Dean William Speer reports in the preceding section, the past year saw a considerable increase in the expression of student concern over the inadequacy of the system. The substance of the message seems to be a question as to whether or not we understand the needs of our students today and whether or not the Freshman Advisory Council is so constituted that it effectively meets those needs. One of the tasks of the new Chairman, Professor Hale V. Bradt, will be to bring together a group of interested and knowledgeable people to explore this question in depth and propose whatever changes in the advisory system appear to be indicated.

The second inquiry involves clarifying the role of the F.A.C. and its chairman with respect to the Offices of the Provost and the Dean for Student Affairs, the Undergraduate Planning Professor, the chairman of the Committee on Evaluation of Freshman Performance, the Task Force on Educational Innovation and other individuals and groups directly or indirectly concerned with the broader aspects of the freshman year. The growing number of people and groups having responsibilities related to the freshman year represent an encouraging trend, yet in an environment where these individuals represent a scarce resource it is of the utmost importance that coordination and cooperation characterize their efforts.

PETER BÜTNER

#### STUDENT COUNSELING

The inadequacies of the counseling system have been the subject of widespread attention during the past year. At the undergraduate level, the Freshman Advisory Council and the Faculty Committee on Academic Performance, in addition to the dean's staff and others, have for many years been concerned with counseling. During the past year the Committee on Academic Performance has intensified its efforts to enlist the co-

operation of the various departments. But what sets the year apart from previous years is the evidence that a greatly increased number of students and faculty believe that the improvement of counseling should be given a much higher priority than it has had in the past.

At the meeting of the Corporation Visiting Committee on Student Affairs the agenda was open-ended so that discussion could move in any direction. Counseling had not been proposed as the main topic. By the end of the meeting it was apparent from the concerns voiced by students and the response of the members of the Committee that the subject of counseling, and its improvement, was of major importance.

Later in the year the dean's office and Professor Schein, Undergraduate Planning Professor, jointly sponsored a conference of counselors from the academic departments and from the fraternities and Institute Houses. As in the Visiting Committee meeting, the improvement of counseling emerged as the major concern.

The important question is, what do people mean by "the improvement of the counseling system?" Do all mean the same thing? Or is it a convenient omnibus phrase by which each of us can refer, imprecisely, to different aspects of the educational process that call for reform? There can be a great potential for good in dissatisfaction with the educational process, provided that the dissatisfaction takes the form of asking the right questions and of stating the right aims.

What is it, then, that students mean by "improved counseling"? We believe that the true root of their concern can best be expressed by thinking in terms of the quality of the human relationships that could and should exist among the members of an institution like M.I.T.

In a special 1968 issue of the *Denver Law Journal* which reported on a conference on "Legal Aspects of Student-Institutional Relationships," a recent president of the United States National Student Association took the other participants to task for missing the point of much of student "unrest." To lift statements out of context has its dangers, but the risk is worth incurring if a major part of student discontent can be expressed by doing so.

Most of you approach social questions in the framework of what I would call procedural liberalism . . . [but] guarantees of individual freedom and political order are insufficient. Men may desire an expanding relationship between one another, a sense of community within their environment which transcends questions of freedom and order. Two lovers do not create courts to handle their quarrels. . . . The problem in mass life involves the creation of a lover's relationship between people. When such a relationship does not exist, modern man feels atomized, cut off, alone, alienated. No number of options in the supermarket, or procedures for his protection, can compensate for his internal sense of loss. . . . The premises upon which procedural liberalism operates [are] that people cannot afford to trust one another, they can only afford to shield themselves and keep

their distance . . . if my analysis is valid, then your intellectual agreements will be insufficient. What will be necessary is almost a psychic shift, by which you begin to view the people and the dynamics of your institutions through different emotional glasses.

Another way of restating this appeal, as it might apply to M.I.T., is to say that students are asking that the implicit values which do in fact order the life of the institution be made explicit, and that the ordering of these values be rearranged. To borrow the medieval theologian's language, they are suggesting that while work is a virtue, it does not belong at the top of the list of virtues, and that charity, in the full sense of the word, belongs at the top.

The BBC television film of two years or so ago characterized M.I.T. as a place whose life and activity were directed by the aim of "How to be First." Now M.I.T. is being asked by many of its students to use its abundant energy and capacity for work to answer the question of how to be truly humane.

The improvement of the counseling system, therefore, does not mean tinkering with a "system"; it means a genuine attempt to strengthen and deepen the quality of human relationships; it means a recognition of the conviction that society's ills cannot be cured by science and technology unless the guiding spirit is that of intelligence directed by charity.

In addition to increasing its general efforts to foster better counseling, the Faculty Committee on Academic Performance, with which the dean's office works closely, has reviewed and, where it felt necessary, revised its policies and procedures.

One of the Committee's responsibilities is to review the academic standing of all students, or at least of all those who may be having academic difficulty, and to make decisions on probation and disqualification. In the past, the time between the delivery by the Registrar of the grade sheets and the meeting at which these decisions were reached was so brief that faculty counsels for seniors, for example, had less than five hours in which to investigate those cases in which the grade sheets gave the first indication that some of their advisees were in academic difficulty. This year, as one of its changes, the Committee postponed consideration of such cases until the following week, with the result that decisions were made on the basis of far more information than was ever available under the old timetable.

WILLIAM SPEER  
RICHARD A. SORENSON

**UNDERGRADUATE SELECTIVE SERVICE**

The policy and problems presented by Selective Service at M.I.T. have continued to be of major concern to the Selective Service Advisory Com-

mittee, currently headed by Irwin W. Sizer, Dean of the Graduate School. Under the guidance of this committee, my office advises undergraduate students on their draft problems. We also handle all correspondence to their local boards. Miss Joanne Robinson, Office of the Dean of the Graduate School, handles such matters for our graduate students.

Selective Service has continued to be a major source of stress at M.I.T. Seniors are faced with uncertainties regarding their future plans for graduate school, employment, and military service. We have continued to advise students to apply to graduate schools as they normally would, since there is so much uncertainty. In addition, many schools are now requesting occupational deferments for their teaching assistants and research assistants.

Of the 1200 first and second year graduate students at M.I.T., 5 per cent have received induction notices this year and have asked the Graduate School to request postponement of inductions. (The Scientific Manpower Commission states that the national average is 25 per cent.) Many more of our seniors than normal have applied for jobs in industry because they feel occupational deferments may be available in industry. In addition, many of the seniors have applied for combined S.B.-S.M. and S.B.-S.B. programs which have a long-standing tradition at M.I.T. The Massachusetts State Appeal Board has generally granted 2-S deferments to all M.I.T. students in the S.B.-S.M. and S.B.-S.B. programs since these students are not awarded their S.B. degree until they complete their programs.

In September 1968, the freshman class was faced with the choice of obtaining a 2-S deferment or remaining 1-A. Those students who choose to obtain a 2-S deferment forfeit their right to be granted a 3-A deferment for fatherhood, and, if a prime age group is named, when their 2-S expires, they fall into the prime age group any time until their 35th birthday.

On the other hand, those students who choose to remain 1-A face several dangers: (1) there is a definite risk over the summer months if the student is not enrolled in summer school; (2) many of the local boards are inducting 19-year-olds already; (3) if a student changes his mind in the spring term and wishes to request a 2-S deferment, the local board may withhold action until the following October, when student verification is sent from M.I.T. to the local board. If this occurs, the student is vulnerable during the summer.

About one-third of the Class of '72 chose to remain 1-A at the beginning of the 1968 fall term. Most of this group are currently changing to the 2-S deferment because they are facing difficulties during the summer months.

President Nixon has proposed to Congress that the 1967 Selective Service Act be changed. He has proposed that the callup procedures be modified by establishing a lottery to determine the order of call from a prime age group. There was no immediate move in Congress to set up hearings on the President's proposal for a change in legislation, therefore, it is unlikely that any action will be taken before winter. Should the President's proposal or any other proposal be passed, we will find it necessary to alter our present policies regarding the draft.

AMY J. METCALFE

#### THE WOMEN STUDENTS

The number of women students and their participation in both academic and nonacademic activities continues to increase. Though women have been students at M.I.T. for almost 100 years, it was not until 1963 that, as a group, they began to become a visible part of campus life. A review of Table I illustrates clearly the increase in their numbers and their widening distribution throughout the academic departments. Though mathematics, biology, and chemistry remain favored as major fields, strong competition is provided by humanities, electrical engineering, economics, and political science.

The Abby Rockefeller Mauzé Professorship, founded "to enrich the professional lives of women students" was held this year by Dr. Rita Levi-Montalcini, a distinguished neurobiologist, who is Professor of Biology at Washington University, St. Louis, Missouri and director of the Center of Neurobiology in Rome, Italy. Dr. Levi-Montalcini spent two weeks at M.I.T. She presented several public lectures and met with the women students informally both in McCormick Hall where she stayed, in the Margaret Cheney Room, and in the Department of Biology.

#### HOUSING

The recreational facilities provided when McCormick Hall East opened in March 1968 are widely used. In fact, since only a very few girls have elected to live off-campus in 1969-70, one concludes that students consider McCormick Hall a pleasant place in which to live. This popularity of the dormitory was somewhat surprising since the students had requested that the on-campus living requirement for single undergraduate women be lifted for upperclassmen.

The old policy which ended in April 1969 was the following:

All unmarried undergraduate women who do not live at home, with the exception of seniors with parental permission to live off-campus, are required to reside in McCormick Hall.

During the two years in which this policy existed, a small proportion of each senior class took advantage of and enjoyed the opportunity to live

VICE PRESIDENT, ACADEMIC ADMINISTRATION

TABLE I

Women Student Registration				
Academic Year	Undergraduates	Graduates	Specials	Total
1968-69	217	175	52	444
1967-68	197	144	38	379
1966-67	186	148	69	403
1965-66	160	136	38	338
1964-65	126	123	37	276
1963-64	103	92	36	231

Women Students — Course Distribution					
Department	1964-65	1965-66	1966-67	1967-68	1968-69
Architecture	13	27	17	19	22
City Planning	0	0	18	18	24
Aeronautics	1	3	3	1	1
Chemical Engineering	7	8	4	6	6
Civil Engineering	2	1	5	4	5
Electrical Engineering	7	9	12	24	24
Mechanical Engineering	2	0	2	3	7
Metallurgy	7	6	7	8	8
Naval Architecture	0	0	0	0	2
Nuclear Engineering	0	0	0	0	2
Economics	28	7	15	16	22
Humanities	8	15	28	16	27
Linguistics	3	6	8	6	12
Political Science	0	13	26	22	19
Psychology	7	6	8	5	6
Management	5	5	5	7	15
Biology	20	34	40	39	43
Chemistry	30	28	37	36	38
Geology	4	9	4	8	7
Mathematics	39	39	39	36	41
Nutrition	21	17	17	18	19
Physics	26	33	35	26	17
	230	266	326	318	371

off campus. These girls thoroughly enjoyed and profited from the chance to live "like ordinary people in the outside world" among persons of all ages and occupations. As a result of this favorable experience and upon the request of the underclass coeds, the dean's staff, supported by the Corporation Visiting Committee on Student Affairs, recommended to the Academic Council that the on-campus residence policy for women be made essentially equivalent to that for men. The Academic Council approved this request. Thus, the on-campus living requirement for single undergraduate women effective for the academic year 1969-70, will be:

All unmarried women members of the freshmen class who do not live at home are required to live in McCormick Hall. Unmarried women members of the three

DEAN FOR STUDENT AFFAIRS

upper classes who wish to reside in McCormick Hall, must contract for residence for periods of a complete academic year which extends from September to June.

This change in policy will give women students a chance to seek variety in their living accommodations.

Despite this new opportunity to live off-campus, almost all girls have elected to remain in McCormick Hall. The distribution of undergraduate women on and off campus is expected to be the following:

Class	McCormick	Off-Campus	
		Single	Married
1973	69	—	—
1972	56	2	1
1971	50	4	4
1970	37	4	10

Because of the demand for rooms by undergraduates it is no longer possible to house women graduate students in McCormick Hall, but the number of spaces in Ashdown House available to women will be increased next year.

During the spring term, each undergraduate living group was given the responsibility for establishment and enforcement of parietal rules. Each group was requested "to review its parietal rules and procedures in the light of this new very liberal policy and to provide the Dean of Student Affairs Office with a statement of what these rules and procedures will be." In its referendum, McCormick Hall voted to abolish all restrictions on parietal rules. A Code of Rules for administering this decision and maintaining security have been established by the dormitory House Committee.

**THE PREMEDICAL ADVISORY PROGRAM**

Interest at M.I.T. in medicine and in biomedical research has increased greatly. The number of M.I.T. applicants for admission to medical schools almost doubled in the past year. One of the reasons for increased interest seems to be a general disenchantment with "research and engineering" and a very sincere desire by students "to do something positive and to work with people." Undoubtedly, the Selective Service Act has also influenced some, who would otherwise not have done so, seriously to consider medicine as a career. Since the number of persons throughout the country that took the Medical Colleges Aptitude Test in May, 1969, was only 10 per cent higher than in 1968, the jump in M.I.T. applicants appears to be somewhat unique. A summary of M.I.T. applications and admissions to medical schools follows:

VICE PRESIDENT, ACADEMIC ADMINISTRATION

Year	Applicants	Admitted	Per cent Admitted
1964	44	28	64
1965	37	26	70
1966	39	25	64
1967	30	22	73
1968	47	40	82
1969	75	50	66

The group of 47 applicants in 1968 included six graduate students, 39 seniors, and two alumni. Three were women. The group of 75 applicants in 1969 includes five graduate students and 70 seniors. Seven were women.

On the average, each M.I.T. applicant applied to about 10 schools. To date 66 per cent have been admitted. In view of the 82 percent acceptance record in 1968 this was perplexing and disappointing. The toughest competition appeared to come from other M.I.T. students who applied to the same school. Although individuals were encouraged to "spread their applications," this was difficult to accomplish because M.I.T. students tended to apply to the same group of schools. In addition, because of their experience and fine academic records, M.I.T. applicants found it hard to believe the relevance of the severe admissions competition. Because medical school classes are generally small (150 or less) no one institution accepts many students from a single university. I believe this factor and the 100 per cent increase in the number of applicants had great influence on M.I.T.'s 1969 acceptance record.

The academic departments in which the medical school applicants majored are identified in the following table:

Department	1968	1969	1970*	1971*	1972*
Aeronautics and Astronautics	1	4	—	—	—
Biology	23	23	19	11	—
Chemistry	2	6	4	3	—
Chemical Engineering	1	1	3	3	—
Economics	1	—	—	—	—
Electrical Engineering	8	16	6	5	—
Humanities	4	12	6	2	—
Management	—	1	1	—	—
Mathematics	1	3	3	3	—
Mechanical Engineering	—	3	2	—	—
Naval Architecture	—	1	—	—	—
Nutrition and Food Science	1	—	—	2	—
Physics	4	3	2	2	—
Political Science	1	2	1	—	—
Civil Engineering	—	—	1	—	—
Undesignated	—	—	1	5	29
	47	75	49	35	29

\* Number identified as of June 1, 1969



As of June 1, 1969, 49 students who plan to submit applications at the end of the summer for admission in September, 1970, have been interviewed in the Premedical Advisory Office. The total number who finally apply will probably be at least 80 or more. An informal and incomplete list of students in the classes of 1971 and 1972, who are at this time seriously considering medicine as a career, includes about 35 in 1971 and about 29 in 1972.

Through the efforts of Dr. Jerome Grossman '61 and his colleagues at the Massachusetts General Hospital, Dr. Peter Block, Dr. Fred Finseth, Dr. Roger Sweet, and Dr. Stanley Wishner, five undergraduate students each spent from one half to one day a week with these physicians following, observing, and learning as much as possible about their working days. This opportunity was greatly appreciated and enjoyed by the students who all gained an increased understanding of what it means to be a doctor. All are enthusiastic applicants for admission to medical school in 1970.

EMILY L. WICK

#### FOREIGN STUDY ADVISOR

In last year's report, I discussed in some detail the guiding thought underlying the work of the Foreign Study Advisor. It was pointed out that he has separate and distinct obligations to undergraduates wishing a junior year abroad (jya), to graduate students who wish predoctoral study abroad, and to the postdoctoral group.

Detailed discussions on junior year abroad possibilities have been carried out with some 80 to 90 students. The total yield from these is not yet clear, but we may have as many as ten or a dozen undergraduates on foreign study during 1969-70. In addition, a substantial number of freshmen have been introduced to the idea, partly as a result of attempting, by a number of means, to reach freshmen to make them at least aware of the possibilities of a year of foreign study as undergraduates. The magnitude and intensity of publicity directed to freshmen and sophomores remains one of the unanswered and probably unanswerable questions. The objective has been to avoid, as far as possible, having a sophomore or junior miss the opportunity for a year of study abroad because he or she had not been made aware of the possibility and practicability of such foreign experience. This, rather than active promotion of foreign study, which certainly is not for everyone, has been the objective. Further progress on introducing incoming freshmen this fall has been made by getting information on jya into the freshman counseling program, the orientation program, and especially in the publication that goes out to prospective freshmen in the summer.

Neither Selective Service nor Student Aid appears to be a serious deterrent to foreign study at the undergraduate level. Registration at M.I.T. of a junior year abroad student as "Undergraduate on Foreign Study," under the authorization by the faculty, suffices to maintain continuity of the students' M.I.T. student status during his year abroad.

At the graduate predoctoral level, this past year has seen major disarray occur. The new Selective Service vulnerability of all graduate students has tremendously decreased graduate student potentialities for foreign study. A second major factor is the radical cutback in government support through the Fulbright-Hayes program for foreign graduate study. A number of the most popular countries have virtually been eliminated, and, even for those countries in which Fulbright funds survived, the total numbers have been cut to a relatively small fraction of their former level. Thus, as far as we are concerned, the formerly important Fulbright program has been virtually eliminated. In response to the Selective Service change and the generally poor climate for graduate study abroad, the Churchill Foundation elected not to make offerings for the year 1969-70. Thus, the Marshall Scholarship program was the one productive program in which we had one successful applicant. Under today's national circumstances, our chief obligation is probably to keep alive the notion of possible benefits of foreign graduate study for predoctoral students, but this is bound to be very much a simmering "back-burner" operation. In spite of the inauspicious circumstances relating to predoctoral graduate study abroad, some 80 to 90 students consulted with me. Thus the role of the long-term idea of benefits of foreign study for graduate students was at least kept alive.

At the postdoctoral level the advisor's principal role is to put potentially interested candidates in touch with the appropriate sources of financial aid, of which there are a great many, for various specialized fields and special groups of people. After this initial contact is made, the various supporting agencies expect to deal individually with the applicants.

Looking back upon this year, I see, as one of the strongly positive aspects of the Foreign Study Advisor's experience, the opportunity for relaxed friendly sessions with substantial numbers of students, many of whom return more than once for further discussions. This, it seems, can contribute not only to the individual students' own growth, but to the cause of more awareness and activity in international awareness and understanding.

HAROLD L. HAZEN

#### RELIGIOUS ACTIVITIES

1968-69 may well be remembered by the supporting staff at the M.I.T. Chapel as the year of weddings, for 141 couples were married in the

Chapel this year. This is an increase of 27 over the previous year and constitutes a new high total. The Chapel has also been the setting over the year for 542 scheduled religious services, eight special services, and for 1,023 other religious and musical programs. These totals are somewhat lower than last year and reflect the discontinuation of most religious services during the summer months.

The performing and visual arts, in addition to the spoken word and the message of silence, continue to make themselves appropriately integral to the environment of this admirably conceived Chapel structure. Without discontinuity to its evocative character, it has contained the weekly Noonhour Recitals arranged by the Institute Organist, Mr. John Cook; the multimedia presentation *Immaterials*, designed by Miss Gretchen Dean; and three chancel dramas, *Carmel*, *It Was in the Stars*, and *Ramath*, written by Mr. William Urbrock and presented at the Sunday Protestant services.

Although the several student religious organizations continue a variety of informal study programs, much time has been given this year to examination of the moral and ethical implications of the issues raised by "Sanctuary," "March Fourth," and "Agenda Days." The religious counselors, again this year, participated in the Freshman Weekend discussion group program, speaking to the topics, "Religion and the College Scene" and "Religion and the Questioning Mind."

Under the auspices of the M.I.T. Hillel Society, the fourteenth series of the Morris Burg Memorial Lectures was presented to the community in November and March. Professor William F. Albright spoke concerning "The Place of the Bible in the Evolution of Human Ways of Thinking," and the topic of Professor Horace M. Kallen was "Black Power, White Power and Education." The society was the recipient this year of a fund in memory of Philip Loew '26, which is to be used to provide selected cultural events. Concert recitalist and ethnomusicologist Ruth Rubin was presented as the first artist in this new program series.

The cooperating ministry of the several Protestant denominations has now been formalized under the title the Cambridge Ministries in Higher Education. Broadly representative of students, faculty, and local clergy, it represents the Methodist, Presbyterian, United Church of Christ, and Baptist campus ministries at both Harvard and M.I.T. Under this arrangement it is anticipated the Reverend James Sessions will continue his primary responsibility here, while being assisted by his new Harvard colleague, the Reverend Lawrence Hill.

The Reverend J. Andy Smith III, representative of the International Ministry and the Baptist Campus Ministries, will leave to accept another assignment. The Reverend John Crocker Jr., Episcopalian Chaplain, and

a former member of the religious counseling staff, will rejoin us in September. It is with deep regret that I must report the death of the Reverend Francis Ayers, in London, last August. Fran Ayers will long be remembered as a most dedicated and capable man.

ROBERT J. HOLDEN

#### STUDENT GOVERNMENT AND ACTIVITIES

In reviewing the various aspects of student life in these categories a year ago it was observed:

Far from existing within a rigid (static) framework these groups and their components are in constant change reflecting the dynamic character of individual students and the student population as a whole.

The events of this past year have demonstrated that the tempo of change is faster and that changes themselves are more fundamental and far-reaching than in past years. Emblematic of the basic changes was the restructuring of the student government legislative group, which was changed from a small committee of 16 to an assembly of 75. There has been a noticeable trend towards increased participation in those student activities which provide total involvement for each student on an equal basis, with the result that those organizations, which require a probationary learning period and have a hierarchical structure, have to work hard to attract new members.

The change in student government, protests at other schools, and the particular interest of the present student generation in the very form of their education, all served to create a renewal of interest in the question of what a student community, and, indeed, what the Institute community, should be. It is indicative of the present generation that these questions were analyzed and discussed in a variety of group gatherings, rather than through the leadership of a few individuals.

Any analyst must conclude that these changes in form and substance represent the continuing vitality of student organizations and a renewed commitment to the institution.

#### UNDERGRADUATE GOVERNMENT

Convinced that the past form of undergraduate government inhibited any direct relationship between those students in positions of responsibility and the concerns of the majority of the undergraduates, several members of the Institute Committee, following a series of open hearings, drafted three proposed constitutions. These proposals were referred by ballot to the undergraduate body in April, and the electorate chose the "Unified University" constitution. The three major features of the new structure established by this constitution were: one, the elimination of the 16 man

“Institute Committee” in favor of a “General Assembly” of 75 members elected from the various living groups (fraternities, Institute Houses, and off-campus residents); two, a formalized procedure for selecting students to serve on faculty committees; and three, an agenda committee composed of students, faculty, and administration to organize the topics for discussion by the General Assembly.

It was the hope of those who drafted this constitution that it would provide a flexible enough structure to allow the student government to become part of an all-Institute government body, when and if such a form of government should develop.

Basic to the “assembly” concept was the assumption that by having assembly representatives closely identified with and responsible to a small group of students, those students would become involved in issues and actions of student government. Furthermore, since the assembly member represented a particular group of students and would thus reflect the attitude of that group, the assembly as a whole could better represent the feelings of the entire student body on any issue. It may be too early to judge their efforts but, thus far at least, the assembly has acted only as a “consensus body” and has yet to develop as a strong legislative group with a character and vitality of its own.

In the revised structure, the several standing and special committees of the previous undergraduate organizations, such as the Student Committee on Educational Policy and the Student Environment Committee, remain unchanged and continue to work productively with parallel faculty committees.

The undergraduate classes, organized for purposes of fellowship and contribution to Institute life, although no longer represented in student government through their class officers, continue to play an integrative role in the undergraduate community.

The Class of 1972, the freshman class, sponsored an evening with Joni Mitchell, a classical folksinger, in concert at Kresge Auditorium. The Class of 1969, the graduating class, established a class fund to support a seminar series of outstanding guest lecturers.

Two new activities under the sponsorship of government subcommittees were added to this year’s calendar. The first, the Karl Taylor Compton Seminars, was established to bring to the campus men and women whose ideas and acts are making major contributions towards solving the problems that beset contemporary American society. The series started with a panel discussion by Claude Brown, Paul Ylvisaker, and Mayors Jerome Cavanaugh and Henry Maier on the topic “Crises in the Cities.” In November, Mr. McGeorge Bundy spoke on new alternatives for peace in Vietnam. In the spring, former Vice President Hubert Humphrey gave

his personal view of the current problems facing America, and John Gardner, the former Secretary of Health, Education, and Welfare gave a challenging report on health in our nation. The series closed the year with a debate on economic philosophy between Paul Samuelson and Milton Freidman. The success of the inaugural year was due to the enthusiasm and efforts of the Series Co-Chairmen, Mark J. Mathis '69 and John B. Harkness, Graduate Student, Course X.

On the lighter side, the Student Center Committee sponsored a Pot Luck Coffee House every Friday night in the Student Center. The bill of fare offered a folksinger, quartet, or informal play with coffee and donuts served free. The coffee house revealed a storehouse of talent here on the campus, as singers and playwrights vied for audiences.

#### UNDERGRADUATE ACTIVITIES

Of special interest to student organizations this year was the service of the Technology Community Association in supplying a computer print-out of the entering freshmen activity interest cards. Arranged by Jeffrey L. Rosenberg, '70, the print-out listed by organization the names of students who had expressed interest in each group. Embracing 117 categories, government, activity, and athletic, the average number of choices was five per student. With the print-out readily available each organization was better equipped to recruit those freshmen who already had a special interest in their particular organization. Taken as a whole, it provided an interesting profile of entering student interest in activities, which had not been available before and which should serve as a bench mark against which to judge changes in interest over the next few years.

As noted earlier there has been increased interest in those groups offering individual members equal opportunities to participate, such as the Outing Club, the Hobby Shop, and the programs of the Student Center Art Studio. Jonathan M. Morey '69, president of the Outing Club, recognized this trend and took steps to equip the club for influx of new members by investing in additional equipment and increasing the scope and variety of club trips. As a result of this active program, the Outing Club was able to attract and hold an unusually large membership.

Aware of this individualistic trend, Mimi Luft, Director of the Student Center Art Studio, took steps to publicize the art program, both the informal noncredit classes and the open workshop aspect of the studio. She staged a series of demonstrations during the noon hour in the main lobby of the Student Center. These demonstrations ranged from feather rock sculpturing and pottery making to jewelry making, and they not only familiarized community members with the art studio, but also provided a colorful noontime activity for those coming to lunch in the Student Center.

During the spring, the campus witnessed a newspaper explosion or "publishing implosion" as one older member of the publishing fraternity referred to it. *Innisfree*, the journal of inquiry, disbanded only to reappear as *Up Against the Wall Street Journal*, a paper to speak for the student left. Not to be outdone, the former editor of *Innisfree*, James A. Smith '69, started a weekly newspaper, *Thursday*. The conservative students then rushed into the battle with *Ergo*. The *Catalyst*, a paper sponsored by the Graduate Student Council, grew from a two page mimeo sheet to a full 12 page paper while, "resisting the pressure to structure its format more consistently along the lines of conventional viewpoints." Needless to say, *The Tech*, "the Grand Old Rag of the Campus" has a fight for the readership of the students on its hands.

#### THE GRADUATE COMMUNITY

This year could have been called the "year of the graduate students" as graduate students either in groups or individually became increasingly involved in the affairs and activities of the Institute community.

The March 4 protest, a day devoted to reviewing the research commitments of M.I.T. and to a symbolic research stoppage, was sponsored by S.A.C.C. (Science Action Coordinating Committee). As Dean Wadleigh has already noted, S.A.C.C., formed by graduate students in the Departments of Biology and Physics, continued throughout the year to bring relevant issues to the attention of the community.

Individual graduate students contributed to various Institute committees. Jonathan P. Kabat, G-VII, and Marvin A. Sirbu Jr., G-VI served on the Review Panel on Special Laboratories. Mr. Sirbu joined by Theodore H. Benttinen Jr., G-XII, will serve on the Corporation's Joint Advisory Committee on Institute Wide Affairs. Stephen H. Kaiser, G-II, and Ralph M. Davison, G-III, served on the Agenda Days support committee.

For their individual efforts, two graduate students were honored at the annual Awards Convocation as recipients of the William L. Stewart Jr. Awards. Given in recognition for contributions to student life, Stephen H. Kaiser, G-II, was cited for his editorship of the *Catalyst*, the graduate newspaper, and Michael R. Terry, G-XIII, was cited for innovations in arranging a program of student counselling in his department.

The Graduate Student Council, the representative body for the graduate student community continues to increase the scope of its activities. Its Muddy Charles, a pub located adjacent to the Council's office offering hospitality in the late afternoon, is receiving increasing patronage. It was the setting for the viewing by a sizable graduate group of the special Channel 2 Agenda Days panel presentation. Among the enumerated purposes of the Graduate Student Council is that of "providing for the wel-

coming of new graduate students." To meet this purpose the Council has over the past few years published an excellent comprehensive "Guide to Graduate Living." In an extension of this service, the Council will sponsor, this coming year, a reception for all new graduate students late in the afternoon of Registration Day.

#### COMMUNITY PROGRAM

Besides the highly unusual events such as "March 4," Sanctuary, and numerous political demonstrations which the community witnessed, there were also both new and old community events in the more traditional vein.

The Walker Student Staff sponsored in April the 35th Annual Assembly Ball which was renamed last year in memory of William A. Carlisle Jr., originator of the Ball and long time friend to generations of staff members. The Tech Dames, the organization of student wives, hosted a fashion show and an International Night. The fashion show, in which the dames themselves modeled all the clothing on display, had a sellout crowd of 300, including a number of husbands. The International Night, set up as a bazaar of booths from the numerous countries represented by the Dames, allowed the entire community to sample the food and beverages of foreign countries and to admire the native costumes of their various hostesses. The evening served as still another indication of the international nature of our student body.

Concerned with lack of communication among the faculty, students, staff, and employees at M.I.T., Maria L. Kivisild, '69, then newly elected U.A.P., asked for ideas on ways in which to alleviate this problem. Philip S. Blackman, G-II, a graduate student and a tutor in East Campus, suggested an all-Institute carnival based upon the idea of a German Oktoberfest. Named The Thing '68, the carnival under Mr. Blackman's leadership brought together over 600 members of the community. Secretaries baked food, students and faculty musical groups entertained, and all enjoyed an evening together. This spring Philip was joined by Richard A. Brooks, G-VI and Robert G. McGregor, G-II in formulating an expanded spring happening, which was dubbed Kaleidoscope. Featured on a sunny Friday afternoon in May were a student-faculty softball game, a pie eating contest, a kite flying contest and a roast beef commons buffet served on the Kresge lawn. The All-Tech Sing competition and a mixed-media show and dance in the evening topped off the day's events.

#### THE AWARDS CONVOCATION

The Awards Convocation, which, through the individual awards presented, seems to sum up the year's achievements, this year saw the fol-



lowing receive the William L. Stewart Jr. Awards for contributions to extracurricular life and the Karl Taylor Compton Awards for outstanding contributions to promoting high standards of achievement and good citizenship within the M.I.T. community.

**WILLIAM L. STEWART JR. AWARD**

**Ivan Raymond Burns '69**

Senior House president, who throughout his four years in the house, gave selflessly to its communal life, while exercising superior leadership to the programs of freshmen orientation and of social activities.

**Alan Marshall Goldberg '69**

A wearer of many hats and with several portfolios, his excellent organizational abilities strengthened and forwarded the programs and events of many M.I.T. activities and student functions. He made ideas work.

**William Billett Grossman '69**

Devoted to music in its many forms, he has contributed spiritedly to most every musical activity on campus. Composer of the score for the Tech Show for the last four years, and of selections for the Concert Band, we now salute him as our "Mr. Music" of the current year.

**Stephen Henry Kaiser, G-II**

Course II Representative to the Graduate Student Council and co-editor of the *Catalyst*, the graduate student newspaper, he has prodded the graduate community, through his prolific writings, to consider the humane issues of our times.

**Anthony Karl Lima '69**

Active in fraternity affairs and editor of *The Tech*, he expressed for many students, through editorials and articles, their feelings and attitudes about un verbalized pressing subjects.

**Jonathan Matthew Morey '69**

President of the Outing Club, whose persistent and efficient leadership over his undergraduate years had added new equipment and programs, and doubled the club's membership.

**David Edward Newman '69**

Chairman of the Society of Physics Students who out of his concern for the quality of education organized procedures whereby undergraduate students were assigned on a one to one basis to work with graduate students who were carrying out thesis research.

**Michael Roy Terry, G-XIII**

Course XIII Representative to the Graduate Student Council who set out two years ago to prove the thesis that the educational process would be improved by better faculty-student communications and proved this

thesis by establishing a number of different types of meetings and activities to accomplish this result.

**James Pennington Truitt, '69**

Chairman of the Interfraternity Conference whose perceptive implementation of the program of Residence Orientation resulted in new patterns of creative interaction and community cooperation.

**THE KARL TAYLOR COMPTON JR. PRIZES**

**Daniel Joel Fingerman '69**

Whose concern for his fellows is reflected by leadership in numerous programs benefiting M.I.T. and the Cambridge community.

**Anthony George, '69**

Whose quiet and selfless leadership has made a lasting contribution to the quality of life at East Campus and to the larger M.I.T. community.

**Peter Quincy Harris, '69**

For sustained and creative efforts to reform educational policy and student government at M.I.T.

**Maria Livia Kivisild, '69**

Who by her example has encouraged greater student concern for all facets of Institute life.

**Mark Jay Mathis, '69**

Leader of his class whose successful efforts brought contemporary issues before the M.I.T. community through the Compton Seminars.

**Robert Gerard McGregor, '69**

For clear perception and outstanding leadership in educational planning and extracurricular activities.

Black Student Union, accepted by co-chairmen Shirley Ann Jackson, Graduate Student and Fred Douglas Johnson, Jr., class of '72.

For its determined and effective role in increasing educational opportunities for Black Americans at M.I.T.

Since the musical and dramatic activities comprise major sectors within the total extracurricular program, both because they involve the major portion of the student body in their performing groups, and because all performances reach the entire campus through their large audiences, it seems appropriate to report these activities separately. Accordingly, the reports to follow are submitted by Professor Klaus Liepmann, Director of Music, and Professor Joseph D. Everingham, Director of Drama.

ROBERT J. HOLDEN

JAY C. HAMMERNES

**EXTRACURRICULAR MUSIC**

The 1968-69 season was very rich in music at M.I.T. The Department of Humanities sponsored ten Chamber Music Concerts at M.I.T. in the

Humanities Series. The Chamber Music Concerts under the direction of Professor Gregory Tucker were given at the Sala de Puerto Rico in the Student Center, the Hayden Music Library, and at Kresge Auditorium. The first concert was given by Joan Esch, cello, with Rowland Sturges, piano. The second concert presented three students: Ray S. Jackendoff (G), clarinet, Stephen D. Umans ('70), clarinet, and Thomas P. Stephenson ('70), bassoon. In this concert Ray S. Jackendoff's Trio was given its first performance.

A concert of music by Paul Hindemith presented Professor Freeman playing piano and oboe, Gregory Tucker, piano, with students A. Showers, flute, Robert M. Hazen ('70), trumpet, Ray S. Jackendoff (G), clarinet. In December Helga Helgason from Iceland gave a harpsichord recital, and Denes and Annaliese Zsigmondy performed on violin and piano. Professors Buttrick and Tucker performed with percussionists at Kresge Auditorium, duo pianists M. & H. Hirschburger presented a recital, and Luis Leguia (Boston Symphony Orchestra) performed on the cello, with Professor Freeman on the piano. Additional performances included a lecture recital of the *Dichterliebe* by R. Schumann by James Olesen, tenor, and Robert S. Freeman, piano; Margaret Ulmer (Wellesley College), piano, Ray S. Jackendoff, Gregory Tucker, Robert Freeman, and E. Eleftherakis, viola, included the second performance of *Elegie* by Gregory Tucker. For the final chamber music concert Kenichi Ohmae, clarinet, and John M. Sandor, piano, presented sonatas by Brahms, Saint-Saens and Zoltán Gárdonyi.

Groups which performed in the M.I.T. Humanities Series coordinated by Professor Tucker were the Camerata Bern, the Borodin Quartet, the Philadelphia String Quartet, as well as Gustav Leonhardt, harpsichord, and Severino Gazzelloni, flute.

The Kresge Organ Series presented two concerts this year. The first, by Piet Kee of Holland, was equally divided between baroque and contemporary organ compositions; the second, by Marilyn Mason, also stressed the contemporary, as well as the baroque and featured new works by Olivier Messiaen, John Cook, Ian Hamilton, and Anthon van der Horst.

Now in its third year, the Thursday Noon Hour Concert Series in the M.I.T. Chapel enjoyed great success in 17 concerts. The programs naturally focused on the use of the organ in the Chapel, but they also included instrumental ensembles and vocal performances, and much use was made of the M.I.T. harpsichord. Admission to these concerts was free, and most of the performing was done by music students at M.I.T. and in the Boston area. This series as well as the Organ Series is coordinated by John Cook.

The M.I.T. Symphony Orchestra, conducted by Professor David M. Epstein, gave three concerts at M.I.T. this year and included an American premiere of *Intrada per Orchestra* by Sven-Erik Bäck and the first Boston performance of *Overture to the Creole Faust* by Alberto Ginastera. Other outstanding works were the *Danse Suite* by Bartók, Mozart's *Duo Piano Concerto No. 10, K. 365* with Professors Buttrick and Freeman as soloists. The Orchestra's tour took them to Amherst College, Brown University, and to Carnegie Hall in New York City, where they had a resounding success.

During Professor Liepmann's leave of absence, John S. Oliver conducted the Glee Club with the Glee Clubs of Douglass College and Mount Holyoke College. In these concerts, works performed were by Bach, Barber, Mozart, Haydn, and the *Gloria* by Poulenc.

The M.I.T. Choral Society, under the direction of Professor Klaus Liepmann, performed Mendelssohn's *Elijah* with members of the Boston Symphony Orchestra. On May 11, under the direction of the interim conductor, Allan Sly, a Walt Whitman Festival Concert was performed featuring works of Vaughan Williams, Holst, Delius, and a first performance of *By Blue Ontario* by Ernst Bacon, contemporary American composer.

The M.I.T. Concert Band, conducted by John Corley, gave two concerts at M.I.T. The fall concert presented works by Kacinskas, Tucker, London, Bavicchi, Andrew Kazdin (S.B., S.M., M.I.T.), all works commissioned by the Concert Band and given premiere performances. The spring concert presented works by Blank, Giannini, the *Symphony* by Paul Hindemith, a first performance of Bavicchi's *Music for Mallets & Percussion*, and *Jericho* by Morton Gould. A special feature of this program was the premiere of *Music for Percussion and Brass* by Stephen L. Weinberg, who is at present receiving the S.B. degree in physics and is a candidate for the S.B. in humanities at M.I.T. The twentieth anniversary tour took the Concert Band to six music centers including the Drexel Institute and the University of Richmond. The program which was enthusiastically received was entirely contemporary and included five pieces commissioned by John Corley for the M.I.T. Concert Band.

The M.I.T. Logarithms celebrated their twentieth anniversary this year with a winter tour including performances in Buffalo, Rochester, Schenectady, and New York City, as well as a television performance in Cleveland. They were hosts for the Log Jam '69 which brought together on one program the Vassar G-Stringers, the Wellesley Widows, the Pembroke Chattertocks, the Colgate Thirteen, the Dartmouth Injunaires, and the Harvard Krokodiloes.

The Concert Jazz Band, under the direction of Herb Pomeroy, played

two concerts at M.I.T. in December and May. Performing at both these concerts were the Jazz Quintet led by Richy Orr (G) and much of the music was composed or arranged by Everett Longstreth and students Richy Orr (G) and Ned W. Lagin ('70). A second Concert Jazz Band has sprung up under the direction of E. Longstreth and made its debut this spring at Kresge. The Festival Jazz Band travelled to Notre Dame, Villanova University, and Quinnipiac College for Collegiate Jazz Festivals and placed well in the finals. The Jazz Band also gave concerts in the greater Boston area and has performed on W.G.B.H.

KLAUS LIEPMANN

#### EXTRACURRICULAR DRAMA

M.I.T. Dramashop presented eight evenings of one-act plays in the Little Theater of Kresge Auditorium for the M.I.T. community during the academic year 1968-1969. Student directors, designers, actors, and technicians produced the plays under the supervision of the permanent drama staff. These evenings were free and audiences were asked to join in a critique of the productions with the student company after each performance. The critiques were followed by refreshments and less formal discussion in the Rehearsal Rooms. The plays performed were the following: October 11 and 12, 1968

*Jack or the Submission* by Eugene Ionesco

*The Measures Taken* by Bertolt Brecht

November 1 and 2, 1968

*Home Free* by Lanford Wilson

*Old Glory* by Dennis Jasudowicz

February 28 and March 1, 1969

*Crawling Arnold* by Jules Feiffer

*Rats* by Israel Horowitz

March 21 and 22, 1969

*Host*, an original play by John T. Melson '69

*Ludlow Fair* by Lanford Wilson

*The General Returns from One Place to Another* by Frank O'Hara

Dramashop's major production for the first semester was a double bill consisting of *Good Day* by Emanuel Peluso and *A Collier's Friday Night* by D. H. Lawrence. These were directed by Professor Joseph D. Everingham and presented on December 5, 6, 13, and 14. It was the American premiere of the Lawrence play.

Visiting Professor Michael Murray served as Director of Drama during the second semester in Professor Everingham's leave of absence. In addition to his other duties, Professor Murray directed *We Bombed in New Haven* by Joseph Heller as Dramashop's major production in the spring.

It was performed on May 1, 2, 3, 9 and 10 and there was a special free matinee on Saturday, May 3, for M.I.T.'s Open House.

In addition to its own program of performances, M.I.T. Dramashop sponsored two evenings of contemporary dance with Toby Amour and James Waring. It also sponsored, with the Department of Athletics, classes in dance technique and composition taught by James Waring during the second semester. The latter were held weekly in the recreation room in McCormick East under the supervision of Mrs. Donald L. M. Blackmer.

A group from Dramashop headed by its president, Richard A. Finberg '70, attended the Yale Drama Festival during spring vacation.

Dramashop officers for the academic year 1968-1969 were:

President: Richard A. Finberg '70

Treasurer: Michael A. Bromberg '70

Secretary: Linda C. Sharpe '69

Publicity: Martinus C. Langeveld '70

JOSEPH D. EVERINGHAM

#### ATHLETICS

The quality and success of the athletic program at M.I.T. is judged by its attractiveness to all students in an educational environment where academic disciplines necessarily are foremost. We define athletics in terms of those objectives which most favorably influence health, physical and mental fitness and generally contribute toward optimal performance in career endeavors.

Over the years, the scope of the Institute's sports program has been expanded beyond the traditional intercollegiate and intramural competitions for undergraduates, to meet the recreational needs of the growing community of women and graduate students, including interested faculty and staff. We have emphasized the development of participation habits in life-long recreational activities. At the same time, we have encouraged and supported the highest level of performance among the large segment of undergraduate men active in our varsity program of intercollegiate competitions in 21 sports.

Additional space in specialized athletic facilities continues to be our most urgent need; and this problem will be compounded as we move closer to a residential campus. High priority should be given to including within the residential complex facilities for squash, tennis, and physical conditioning by the casual participants not attracted to the formal team sports program. This is especially imperative if the Institute hopes to accommodate the recreational interests of increasing numbers of women and graduate students living on campus or nearby.

A decade ago, the Institute's sports facilities were quite adequate to

meet the needs of the M.I.T. community of that era. In fact, Alumni Pool remains one of the better indoor collegiate swimming pools in the East. However, a single pool will no longer accommodate the M.I.T. aquatic program which has developed in recent years to include water polo, white water sports, scuba instruction, and a variety of community swimming programs, in addition to the traditional instructional and competitive programs for undergraduates. Similarly, the M.I.T. Sailing Pavilion, for many years the finest university sailing facility in the country, is in very real need of an extension to include two boat bays and additional docking space of approximately 90 feet to accommodate the immediate and foreseeable M.I.T. sailing interests.

In addition to the expansion of existing high quality facilities such as Alumni Pool and the Sailing Pavilion, it is imperative that we construct a covered ice skating rink and replace Rockwell Cage with a multi-purpose and modern indoor facility readily adaptable to large convocations, such as Commencement.

It is encouraging to note that the Planning Office is currently compiling data to support a master plan for the development of the total needs of the West Campus, including athletics. Hopefully, funds will be available in the not too distant future to move ahead in the construction of these much-needed athletic facilities as well as those other elements which will provide for a better campus environment.

#### PROGRAM HIGHLIGHTS FOR 1968-69

**PHYSICAL EDUCATION** The basis for a program providing opportunities for athletics and recreation for all students, in which the Institute takes great pride, is top quality instruction in those sports skills selected by the individual students to be consistent with their interests and/or physical capacities. At this point, it should be noted that the athletic requirement for undergraduates is limited to men simply because we are lacking in staff and facilities to extend the requirements to all women. Presently, about one-fifth of the class of entering women manage to register for instruction in a sport of their choosing. However, a number of women have been refused registration in squash instruction because all available space had been committed to male registrants. The opinions expressed by coeds at McCormick Hall invited to meet with the Athletic Board indicated much interest in extending the requirement to undergraduate women.

All male undergraduates meet desirable swimming standards or receive instruction as needed. Following an evaluation of swimming ability and physical fitness, a student may then select a program in freshman inter-collegiate athletics or instruction in any of the sports listed on the following page. Classes are small enough to ensure individual instruction.

VICE PRESIDENT, ACADEMIC ADMINISTRATION

This past year there were 3,763 registrations in 49 physical education courses, including 553 noncredit registrations. Registration statistics are as follows:

Physical Education Registration 1968-69		
Swimming		700
<i>Beginning</i>	335	
<i>Intermediate</i>	67	
<i>Diving</i>	74	
<i>Red Cross Life Saving</i>	67	
<i>Red Cross Instructors</i>	104	
<i>Scuba Diving</i>	53	
Tennis		449
<i>Beginning</i>	295	
<i>Intermediate</i>	154	
Development		423
Sailing		360
Ice Skating		243
Golf		192
<i>Beginning</i>	155	
<i>Intermediate</i>	37	
Fencing		168
Rifle		156
Squash		149
Judo		141
Pistol		136
Volleyball		135
Archery		120
Skiing		103
Badminton		78
Softball		64
Lacrosse		44
Touch Football		43
Soccer		30
Wrestling		29
		<b>3,763</b>

Noncredit Registrations	
Classification	Number Registered
Undergraduates	
Freshmen	38
Sophomores	162
Juniors	93
Seniors	83
Graduate Students	158
M.I.T. Staff	17
Wellesley Staff	1
Alumni	1
	<b>553*</b>

\*includes 79 women



**INTERCOLLEGIATE ATHLETICS** The traditional image of athletics at M.I.T. generally fails to reflect the quality of our intercollegiate program and the interest in varsity athletics which exists among a large segment of our students. This past year approximately 900 undergraduates represented M.I.T. in 434 freshman, junior varsity, and varsity contests in 21 intercollegiate sports.

The records of seven of our varsity teams rate among the finest in the history of M.I.T. athletics:

The cross country squad climaxed a great fall season by winning M.I.T.'s first I.C.4A. College Division Championship representing the Eastern Colleges, and placed fourth in the National College Division Finals held at Wheaton College, Illinois. The squad was led by Ben Wilson '70 who was undefeated in dual meet competition.

The wrestling squad, in winning 15 of 17 dual matches, broke every team and individual record by averaging 34.4 points per match while limiting their opponents to an average of 8 points. The tastier victories included wins over Harvard and Dartmouth.

After a rather mediocre early season performance, the swimmers won their last 7 meets. Lee Dilley '69 and Alan Graham '71 won individual New England Championships in the 200 yards freestyle and the 400 yards individual medley, respectively.

The lacrosse team won 9 consecutive New England League contests before bowing to the University of Massachusetts 12-9 for the New England Championship.

The lightweight crew finished second only to Harvard in their national championships. At this date, the determined M.I.T. oarsmen are en route to England where they will compete for the Thames Cup in the Henley Royal Regatta.

The tennis squad compiled 13 victories against 4 defeats for its best season in years, including single point victories over Yale and Brown.

The sailing team represented New England and placed fourth in the National Dinghy Championship.

In summary, our M.I.T. teams do compete favorably without the pressures of overemphasis and exploitation often associated with intercollegiate athletics. Of special significance is a review of the number of awards presented to those young men who evidenced dedication to team interests and the disciplines which characterize varsity athletics. A total of 628 awards in 21 sports include 259 varsity letters, 66 junior varsity, and 303 freshman class numerals.

**INTRAMURAL ATHLETICS** Intramural athletics at the Institute are organized and administered by the undergraduate Intramural Council which is composed of the managers of each of the sports sponsored by the

Council, plus representatives of the Institute Houses and the Interfraternity Council. The teams are organized around the residential living groups, which motivate the high morale characteristic of the intramural competitions.

This program regularly attracts the largest segment of student participation in organized athletics at M.I.T. A review of the participation statistics will attest to the quantitative impact of intramural sports upon the student community. However, the quality values are directly related to the insight and organizational ability of the undergraduate manager in each sport. He must accurately classify according to ability the teams in the several leagues within each sport to ensure competitive interest throughout the season. Capable referees and umpires must be recruited to officiate the games at a level consistent with the importance attached to these competitions by the students. The future success of the intramural program will be assured as long as students continue to accept the responsibility of implementing a program geared to the interests of the entire student community.

Intramural Participation 1968-69			
Sport	No. of Teams	Average Number Players per Team	Participants
Badminton	Singles and Doubles Tournament		165
Basketball	83	10	830
Bowling	67	5	335
Cross Country	28	6	168
Touch Football	48	18	864
Golf	26	4	104
Hockey	38	12	456
Rifle	30	4	120
Sailing	8	4	32
Softball	67	14	938
Soccer	15	15	225
Squash	42	5	210
Swimming	16	10	160
Table Tennis	66	3	198
Tennis	53	7	371
Track	14	12	168
Volleyball	70	9	630
Water Polo	16	12	192
Wrestling	22	8	176
	738		6,458

**CLUB ATHLETICS** An athletic "club" differs from a varsity team in that there are no eligibility rules generally associated with intercollegiate athletics. Rugby is quite typical of a club. Graduate students and members of the teaching staff often join with undergraduates to participate in their

special interest, for which there is usually no counterpart among the 21 intercollegiate sports. The Department of Athletics makes available field facilities, essential equipment and limited subsidy for competitions.

A zest for competition plus the joy and satisfaction of informal team effort are high among the motivating forces which account for a surging interest in club athletics. Clubs active in 1968-69 were:

Club	Roster
Badminton	12
Cricket	15
Graduate Crew	14
Graduate Gymnastics	6
Graduate Soccer	25
Ice Hockey	18
Judo	38
Karate	45
Rugby — 2 clubs	30
Scuba Diving	23
Water Polo	15
White Water	18
	259

**ATHLETICS FOR WOMEN** The interest of M.I.T. women in recreational athletics continues to increase with each new class of undergraduates. Prof. Silvio Vitale was appointed Coordinator of Women's Athletics this past spring with the responsibility of expediting the assignment of space and general needs of the women's program. He will also coach their fencing team.

The completion of the second tower of McCormick Hall included a modest recreation room which now accommodates modern dance, fencing, and badminton, in addition to small social functions.

Intercollegiate sailing is one of the more highly organized sports among college women. With M.I.T. as the host, the New England Women's Intercollegiate Sailing Association sponsored the third annual National Women's Sailing Championships in the Charles River Basin this past June 12-14. Nine colleges representing the Midwest, South, Middle Atlantic, and New England Districts competed for the championship eventually won by Radcliffe, with M.I.T. finishing in second place.

Kathy Jones '71 is Chairman of a Women's Athletic Committee, composed of representatives of sailing, fencing, rowing, mixed volleyball, modern dance, cheerleading, and field hockey. The committee currently is preparing a proposal for athletic awards in those sports which compete at the intercollegiate level in the Greater Boston area. In addition to an awards program, the Department of Athletics will assist in the imple-

mentation of further athletic activity as new interests are reflected through the Women's Athletic Committee.

**CASUAL RECREATION** It is difficult to make a statistical report of the extent of the casual use of the Institute's athletic facilities for general recreation by the M.I.T. community. It is more difficult to estimate the number of individuals and groups who are denied recreational opportunities during the prime hours between 4:00 and 7:00 p.m. because all facilities of the athletic plant are preempted by the formal aspects of the undergraduate program, intercollegiates and intramurals. The annual sale of Athletic Cards indicates that approximately two-thirds of our students and a large segment of the faculty and staff are active in one or more facets of sports recreation.

Athletic Card Sale for 1968-69	
Students	5,357
Faculty/Academic Staff	547
Staff/Employee	1,345
Alumni	167
<b>TOTAL</b>	<b>7,416</b>
Sailing Cards	1,520

An M.I.T. Jogging Program was initiated this year which attracted approximately 125 graduate students, faculty and staff in a training program supervised by Peter Close, Director of Sports Information and former Olympic middle distance runner. Following a period of orientation and gradual conditioning during the noon hour, the joggers were encouraged to continue a program and schedule best suited to their individual needs.

As in previous years, a partial list of additional Institute community recreational opportunities included a fall tennis tournament, noonhour volleyball for men, Mrs. Lettvin's conditioning classes for M.I.T. women, tennis instruction, sculling instruction at Pierce Boathouse, faculty-staff squash competitions regularly in the Massachusetts Squash Racquets Association B, C, and D Leagues, the Nautical Association Sailing Program, swimming and ice skating instruction for faculty and staff children on Saturday mornings, Instrumentation Lab noon hour softball and a similar league for graduate and summer session students in the late afternoon.

The M.I.T. Summer Day Camp completed its eleventh year with a capacity enrollment of 620 youngsters in 4 two-week periods. The camp utilizes the Institute's athletic facilities to provide enriching experiences for faculty and staff children not usually associated with day camp activity in an urban setting.

**CAMBRIDGE-BOSTON COMMUNITY** The Department of Athletics has made athletic equipment and facilities available to the metropolitan Boston community whenever possible. During the past academic year, we initiated a plan for M.I.T. students in the Tutoring-Plus Program to bring a Cambridge youngster on a one student-one guest basis to any of the athletic facilities during the open hours at the various facilities. The usual guest fee was waived and each tutor assumed supervisory responsibility while his guest was on campus. Also, during the few periods of relatively low student participation, we have extended the use of a facility to M.I.T. student tutors for group events.

A sampling of the variety of programs in the area during the past year included a sailing symposium for junior sailors in the Massachusetts Bay, summer athletics for two Bridge Upward Bound programs based at the Institute, a swim instruction program for Cambridge Boy Scouts sponsored by Alpha Phi Omega, guest athletic privileges to summer employees at the Institute under the Mayor's Program, the Wheel Chair Olympics sponsored by the Massachusetts State Paraplegics Association, the Cambridge Jay-Cee Youth Track and Field Championships and a number of one-day events which could be accommodated during recess or other off-peak hours.

**MAJOR ATHLETIC AWARDS FOR 1968-69**

The Class of 1948 Award to the senior athlete of the year

Jeffrey M. Weissman '69

The Admiral Edward L. Cochrane Award to the senior who best combines qualities of leadership, humility, and scholarship in the intercollegiate athletic program

George A. Hustak '69 and James R. Yankaskas '69

The Eastern College Athletic Conference Merit Medal to the scholar-athlete of the year.

Geoffrey G. Hallock '69

The Straight T Award, the highest award for athletic performance at M.I.T.

Lee A. Dilley '69, Alan K. Graham '71, Thomas Imrich '69, John V. Maxham '69, David W. McComb '70, Bruce C. Wheeler '71, and the 1969 Varsity Lightweight Crew

The Burton R. Anderson, Jr., Award to the manager of the year  
Robert N. Schulte '71

The Quadrangle Club Award to the freshman athlete of the year  
Albert Lau '72 and Pete A. Sanders, Jr. '72

The Varsity Club Award to the living group with the most varsity lettermen  
Beta Theta Pi

The M.I.T. Pewter Bowl for outstanding contributions to women's athletics by a fourth-year woman student

Maria L. Kivisild '69

**ATHLETIC STAFF**

Changes in the staff of the Department of Athletics during 1968-69 were as follows: John S. Merriman Jr., former Assistant Director of Athletics and, in recent years, Supervisor of Intramurals and Coach of Golf, retired; David Michael, formerly Coach of Freshman Swimming and Instructor in Physical Education, was appointed Supervisor of Intramurals; Jay D. Moxley was appointed Instructor in Physical Education and Coach of Freshman Swimming; Gerrit W. Zwart, part-time Coach of Lightweight Crew, resigned to devote full time to his career as an architect; Jack H. Frailey, part-time Coach of Heavyweight Crew, will replace Mr. Zwart; Peter A. Holland, formerly Freshman Crew Coach at Dartmouth, was appointed Assistant Professor in Physical Education and Head Coach of Rowing; Professor Silvio N. Vitale, Coach of Varsity Fencing for 18 years, was appointed Coordinator of Women's Athletics for the coming academic year; Edwin A. Richards, member of the United States Olympic Fencing Team in 1964, was appointed Coach of Varsity Fencing on a part-time basis; James L. Hutt, part-time Coach of Gymnastics, resigned; Robert F. Lilly was appointed Instructor in Physical Education and Coach of Gymnastics; Alan W. White, Business Manager and Assistant to the Director of Athletics since 1964, died suddenly on April 25, 1969; and Roderick R. Arthur, formerly Administrative Assistant in Physical Plant, was appointed Business Manager and Assistant to the Director of Athletics.

ROSS H. SMITH

**STUDENT AID CENTER**

The past year saw some significant developments in M.I.T.'s financial aid program. As a major result of the increase in tuition from \$1900 to \$2150, the number of students needing assistance and the average demonstrated need of those students increased markedly. On the other hand, the proportion of the average student's need being met with scholarship decreased significantly, while the average loan was higher than in previous years.

Scholarship and loan awards made to undergraduates from all sources totaled \$4,754,363, a 13 per cent increase over 1967-68. This aid was distributed to 2,337 undergraduates, an increase of 167 students over last year. Of these, 2,042, 87 per cent of all aid recipients, were judged to have need for financial assistance. The full need of each of these stu-

## STUDENT AID CENTER

dents was met by scholarship and loan awards. In addition, 295 students received aid not related to financial need, from sources outside the Institute. Table I shows the sources and disposition of the aid funds administered this year and last.

The average scholarship award this year was \$1,210, compared with \$1,330 last year; the average loan this year was \$943, a new and significantly high plateau.

### SCHOLARSHIPS

We are happy to report the establishment of ten new endowment funds for scholarships, increasing the total endowment by \$2,248,078. The scholarship endowment now stands at \$18,305,678. Funds were established by bequest, in the names of Constance and Arthur H. Ballard, Abraham and Ida Kalker, Li Ming, Malcolm Oliver Petri '28, Henry Arthur Waterman '96, and Howard I. Wood '01. A new scholarship fund for undergraduate and graduate students in architecture was established in memory of Francis Ward Chandler. An undergraduate scholarship fund in honor of George J. Leness '26 was made available by the Merrill Lynch, Pierce, Fenner and Smith Foundation. A fund named in honor of Harold O. Whitney '16 was established by the Class of 1916. The income from the scholarship endowment provided \$1,270,914 in scholarship awards this year.

New gift scholarships were established this year by the Garrett Corporation, in honor of Walter R. Ramsaur, and by Dr. and Mrs. Charles Y. Hu, in honor of Robert Hsueh-Ko Hu '65. In addition to these new funds, several sponsors of gift scholarships increased the amount of their annual gift in recognition of the increased educational costs at M.I.T.

However, the net increase this year in scholarship assistance made available from all outside sources was much less than in the recent past. In all, \$1,174,528 in gifts and predesignated awards was given to M.I.T. to distribute, an increase of only 2½ per cent over last year. We continue to see donors of long standing re-evaluating and diminishing or discontinuing their undergraduate scholarship programs at M.I.T.

An allocation of \$298,990 from M.I.T.'s operating funds augmented the designated scholarship resources this year. These funds were distributed to 364 students.

### LOANS

For the first time in the history of our aid program, a significant strain was imposed on our low-interest loan funds, necessitating the modification for the coming year of the terms of Technology Loan Fund notes, and the establishment of new policies relating to loans made to graduate students.

As Table II implies, both the Technology Loan Fund and the National

**Table I Undergraduate Scholarships and Loans, 1968-69**

	1968-69		1967-68		Total
	Number	Awards	Number	Awards	Total
Undergraduate scholarships					
From M.I.T. endowment funds:					
Freshman scholarships	403	\$386,679	348	\$ 327,698	
Upperclass scholarships	967	884,235	928	1,007,770	\$1,335,468
From M.I.T. operating funds:					
Freshman scholarships	74	61,484	71	77,182	
Upperclass scholarships	290	237,506	217	240,449	317,631
From outside sources:					
Freshman scholarships	396	389,180	357	333,883	
Upperclass scholarships	799	785,348	780	813,179	1,147,062
<b>Total undergraduate scholarships</b>	<b>2,264</b>		<b>2,102</b>		<b>\$2,800,161</b>
Undergraduate loans — As awarded					
From M.I.T. sources:					
Freshman loans	878	408,322	762	291,979	
Upperclass loans	2,097	1,366,389	1,771	857,453	1,149,432
From outside sources:					
Freshman loans	59	54,915	89	79,316	
Upperclass loans	174	180,305	163	162,325	241,641
<b>Total undergraduate loans</b>	<b>2,067</b>		<b>1,772</b>		<b>\$1,391,073</b>
<b>Total scholarships and loans</b>	<b>2,337</b>		<b>2,170</b>		<b>\$4,191,234</b>
Undergraduate loans — Sources					
Technology Loan Fund	1,013	502,341	1,021	352,167	
National Defense Student Loans	1,139	664,650	1,054	573,353	
Other M.I.T. loan funds	823	607,720	458	223,912	
<b>Total undergraduate loans from M.I.T.</b>	<b>1,881</b>		<b>1,569</b>		<b>\$1,149,432</b>



STUDENT AID CENTER

Defense Student Loan Program were used to the fullest extent possible — all available funds were loaned to students — and the year's demand required a greatly accelerated use of the capital of several other loan funds available to the Institute to administer. The total loaned from all sources, \$2,601,847, exceeds, by a considerable amount, the highest previous year's figure, \$2,009,191 in 1966-67. The loan resources available in the National Defense Student Loan Fund essentially matched last year's amount, but it is now almost certain that a significant reduction in new federal capital addition to the NDSL Program is in store for next year.

It is clear that we are entering upon another period of dynamic change inaugurated by ever increasing educational costs. The immediate future will see significant changes in the structure of our financial aid program, and, in the use of our resources, we shall place even more emphasis upon meeting the financial need of our students. We expect to see reduced further the role that academic performance in high school will play in determining the amount of gift aid awarded an incoming freshman. We expect to see applied more universally the concept of a uniform level of "self-help," loans and campus employment, which is substantially similar each year for all students seeking financial help. We expect, in short, to meet the challenge of the ever increasing demand for financial aid by the most equitable program we can devise. This program, whose pervading objective is to allow every student at M.I.T. to pursue his education without oppressive financial strain, will attempt less than ever before to reward the "superior" student and, of necessity, penalize the "mediocre" student.

We are pleased to announce that at the end of the academic year the Office of Student Personnel became an integral part of the Student Aid Center. Mr. Edward J. Carey, Jr., the Director of Student Employment, has assumed the additional title of Associate Director of Student Aid.

JACK H. FRAILEY

**Table II Loans to Students from all M.I.T. Sources, 1968 and 1969**

	1969		1968	
	Number of Loans	Amount	Number of Loans	Amount
Technology Loan Fund	1,147	\$ 659,696	1,270	\$ 654,894
Other M.I.T. Loan Funds	1,135	926,134	560	266,917
National Defense Student Loans	1,255	816,941	1,220	811,103
Installment Credit Plan	225	181,171	200	127,930
Ford Forgivable Loans	10	17,905	16	34,470
<b>Total</b>		<b>\$2,601,847</b>		<b>\$1,895,314</b>
<b>Number of loans</b>	<b>3,772</b>		<b>3,266</b>	
<b>Number of recipients</b>	<b>2,586</b>		<b>2,232</b>	

NB: Includes both undergraduate and graduate students.

## ADMISSIONS OFFICE

Statistical data on Admissions Office operations for the year 1968-69, comparable to those presented in previous years, appear below.

### TRENDS

Somewhat surprisingly, the number of applications for freshman admission was significantly higher than in previous years, more than 10 per cent increase in preliminary applications, and 9 per cent increase in completed finals. Part of, but only part of, the increase is accounted for by the markedly larger number of applications from members of minority groups, as discussed in some detail below. Yield, the index of how we fare in terms of our "competition," remained strong this year, at just about 65 per cent.

The number of applications for admission as transfer students continued to grow as the flexibility and breadth of our curricular offerings become more widely recognized. The number who are admitted and matriculate each year continues to be somewhat fewer than 100 because of the strict policies relating to evaluation and housing — the transfer applicants are told that on-campus housing will *not* be available. More liberal policies in these respects, and in the offering of financial aid, could produce significant increase in number of acceptable transfers.

### GRADUATE APPLICATIONS

The total number of graduate applications continued to be large, despite the impact of the draft. The past year was up slightly over the unprecedentedly high figures for 1967-68. Factors such as the draft and the cut-back in fellowships and assistantships have reduced the net yield, and have multiplied the problems of over-admitting and of second- and third-round offers of aid. Although the number of cancellations this year seems to have been more than last, there is a relatively large enrollment in the Graduate School this September with new matriculants the same as a year ago.

The interest of foreign students in M.I.T. at the undergraduate level, as well as the graduate level, continues to grow. Because supporting data is so different for most foreign students, it is impossible to make direct comparisons between their qualifications and those applying from the U.S. However, it appears that artificial restraints, such as finances and, perhaps, more vigorous interpretation of credentials, are necessary to keep the number of foreign students at approximately present levels. Certainly, a decision to offer financial aid to entering undergraduates on the same basis as is done for U.S. students would markedly increase the number

#### ADMISSIONS OFFICE

of admissible graduates, especially from Asian countries. Policies for dealing with these problems require thorough study.

#### SPECIAL ITEMS

Four major subjects attracted the special attention of Admissions personnel during the year: the availability of an education for members of minority groups, the admission of foreign and transfer students, the draft, and the special review of policies and practices by the Faculty Committee on Undergraduate Admissions and Student Aid.

#### MINORITY GROUPS

The conviction that an M.I.T. education should be available to larger numbers of persons who have suffered from prejudice or economic deprivation has led to significant increases in some aspects of the recruiting program and in further extrapolation of some selection procedures.

For some years we have stressed school visits to predominantly black schools and to other schools serving minority group areas; we have had disproportionate representation in our annual Guidance Conferences from such schools. We continued those practices this past year, and added emphasis in two directions:

1. We arranged for 11 student members of the M.I.T. Black Student Union to visit schools in various urban centers, both in the north and south, which had produced winners of National Achievement Scholarship Awards (nationwide competition for students who identify themselves as Negro). These visits were informative both to the Admissions Staff and to the student visitors. We believe they helped immeasurably to interpret M.I.T. to the schools visited, as well as to enhance the general image of M.I.T. in locales where the only image had really been "unattainable." We anticipate that the visits will result in more student applications from these schools in future years, even though the number of students this year directly attributable to these visits was small. (In general, it has been our experience that the results of school visits accrue over a period of several years rather than immediately.) We must continue this practice, at least until we obtain more precise indications of the over-all effectiveness of the visits.

2. We departed from precedent to the extent of undertaking direct mailings to a large selective list of the National Achievement Scholarship qualifiers (totalling nearly 2,000), inviting them to consider M.I.T., if their college objectives lay at all in our direction. The response from this was rewarding. Much of the four-fold increase in completed applications can be attributed to this program and to the mailing of special literature to guidance counselors in predominantly minority-group schools. For the

immediate future, this promises to be a very productive process for informing people, who might otherwise overlook M.I.T., that the Institute may offer them real opportunities.

For many years we have recognized that factors of socio-economic and educational background are important in interpreting CEEB test scores. This is dramatically relevant in regard to the Verbal Aptitude Test, but also seems to be significant with respect to the Achievement Tests, which are intended to reflect preparation rather than just "potential." These tests scores, directly interpreted, seem to be a good predictor of freshman academic performance, but it is also clear that many entering students with good school records but relatively poor CEEB tests have been able to catch up, and even to prosper, as they go through the upper years.

In keeping with these empirical observations, we endeavored this year to find and admit a significant number of applicants whose general indices suggest that they were good candidates even though their CEEB test scores, or some of them, were at what we have in the past called dangerous levels. We offered admission to approximately 70 applicants in this category, although it is in no sense possible to draw a clear line between these and the other admissible candidates, and we expect about 45 to matriculate in September. Most of these were invited to attend, and did attend, a special summer session called Project Interphase intended to enrich their preparation and better orient them toward M.I.T. Approximately three-fourths of these were black Americans.

The Admissions Office has straightforward means of identifying most black applicants, such as those who associate themselves with the National Achievement program or one of the special agency programs devoted to talent search. However, we do not officially classify an applicant by race at any stage of the proceedings. We estimate that some 185 of the completed applications this year were from black Americans, and that there will be about 54 of these in the entering class.

We are trying to modify procedures relative to evaluation and admission of minority group applicants for transfer and special student status in much the same vein, but have not yet had experience with many such students. In widely differing directions, comparable efforts to encourage minority group applicants at the graduate level have been carried on by the Graduate School Office and many of the departmental offices, as well as by the Admissions Office.

#### TRANSFER AND FOREIGN STUDENTS

As was indicated above, the admission of foreign undergraduates and of transfer students follows procedures and standards roughly comparable to the admission of freshmen from U.S. secondary schools. The numbers of

applicants, and of matriculants, are kept in control by application of somewhat different criteria for allocation of housing and financial aid. Transfers are informed that the Institute assumes no responsibility for providing housing, and that regularly registered students and entering freshmen have precedence. Foreigners have very little chance of receiving financial aid from the Institute, are so informed, and are customarily denied admission if they cannot assure financial backing.

If these restraints were not emphasized in the literature, in the correspondence, and in practice, the number of qualified applicants in each category would expand greatly. From the viewpoints of the students, the rationale for the differential treatments defined above is not at all clear — certainly the transfer has at least as much *need* for on campus housing as the student who has lived here for four or six semesters. Accordingly, there is great need for systematic review of general Institute policy in these directions to determine what restraints, if any, should be imposed on the recruiting and admission of transfer and foreign students and how best to apply these restraints.

#### THE DRAFT

Threat of the draft has certainly affected the application situation in the Graduate School and the pattern of such items as the two-degree program. However, its effect on the undergraduate admissions program has been imperceptible. The number of graduate applications is barely holding its own, in the face of what would normally have been (from all previous studies) a measurable increase. The yield is down slightly, for many who have graduate school as *an* alternative apparently prefer to take industrial jobs which may afford occupational deferment. The magnitude of these phenomena, and the number of graduate students who have been drafted, are significantly below what was anticipated in the spring of 1968, and have had less recognizable effect on enrollment than has the marked reduction in government-sponsored fellowships and research assistance-ships. The total graduate school enrollment in 1969-70, instead of falling below what it has been in the two previous years, ended up this fall as slightly higher than in any previous year.

#### COMMITTEE ON UNDERGRADUATE ADMISSIONS AND STUDENT AID

The Committee on Undergraduate Admissions and Student Aid has continued its basic study of undergraduate admissions procedures throughout the year. A preliminary report was submitted to the Faculty at the end of the year, but the full report and recommendations will not be ready until sometime in the year 1969-70. In the meantime, the staff is implementing some of the tentative recommendations, both in the area of

minority group recruiting and in several aspects of the normal programs. The Committee has helped with some substantial revisions of Admissions Office publication policy, and is working on procedures which may bring about more significant participation of the Committee members, and other faculty members, in the actual selection process.

#### OPERATIONS

As of January 1, the staff was augmented by the appointment of John A. Mims, as an Assistant Director of Admissions. Mr. Mims, with experience in Chicago State College, where he specialized in working with black Americans, will assist with the varied assignments typical of all members of the staff, but will also specialize in the recruiting, selection, and counselling of blacks and members of other minority groups.

William H. McTigue, able and indefatigable Director of the Educational Council, resigned to return to private industry as of April 1. His yeoman services to the Admissions Office, as well as to the Council, will be greatly missed. His associate, William J. Hecht, is admirably qualified to assume responsibility as new Director of the Council. The work of the Council is summarized below.

After three years of service in other offices of the Institute Robert K. Weatherall was fortunately available on a half-time basis, and his assistance was greatly appreciated, especially in coping with many of the peak load problems.

Five members of the staff (Mrs. Juanita L. Stuller, Messrs. Hecht, Peter D. Leavitt, Peter H. Richardson, and Robert D. Schuiteman) have served this year as freshman advisers, and Mr. Leavitt continues as Counselor for Special Graduate Students in Course VI. M. Bryce Leggett completed a thirteen-year tour of duty as Executive Secretary of the Atoms for Peace Awards, and is currently assisting in preparation of their final report.

Eugene R. Chamberlain took office in April as the President of the National Association for Foreign Student Affairs. His associates, Mr. Schuiteman and Mr. Leavitt, are also active in this major national organization of university personnel involved in work with foreign students.

The extraordinary emphasis placed this year on recruiting of minority group students forced curtailment of normal high school visiting programs. The number of schools visited declined appreciably; a larger proportion of the visits were to group sessions, where representatives of several schools were called together to meet with representatives from Cambridge and, usually, from the local Educational Counselors. The Office is indebted particularly to faculty members Dwight M. B. Baumann, Secor D. Browne, Charles K. Crawford, Philip Morrison, Daniel E. Whitney, and Bernhardt J. Wuensch for their combination lecture and school

ADMISSIONS OFFICE

Admissions Office Statistics, 1968-69			
	1967	1968	1969
<i>Entrants from secondary schools:</i>			
Preliminary applications	6,240	6,414	7,219
Final applications	3,887	4,218	4,582
Admissions offered	1,416	1,512	1,479
Actual registrations	918	960	966
Registrations as per cent of admissions	64.8%	63.6%	65.3%
Number of secondary schools represented	713	744	729
Per cent of students from nine northeastern states	53%	47%	51%
<i>College transfers:</i>			
Total applications	497	510	637
Applications completed	217	235	318
Admissions offered	85	109	131
Actual registrations	78	96	109
Registrations as per cent of admissions	92%	88%	83%
<i>Graduate students:</i>			
Total applications	5,672	6,077	6,189
Admissions offered	2,284	2,038	2,333
Actual registrations	1,769	1,255	1,256
Registration as per cent of admissions	77%	62%	54%
<i>Number of personal interviews:</i>			
At M.I.T.	1,514	1,555	1,916
By Educational Counselors in New York City	187	204	226
Other Regions	4,999	5,369	5,841
Total	6,700	7,128	7,983
Number of persons taking tours of M.I.T.	5,860	5,552	4,878
<i>Number of secondary schools visited:</i>			
By Educational Counselors (College nights)	91	115	123
By Faculty and Administrative Staff members	239	126	81
By Admissions Office staff	309	312	170
By students	—	—	144
Total	639	553	518

Advanced Placement

	Number of students seeking credit		Number of students receiving credit		Number of subjects credited	
	1967	1968	1967	1968	1967	1968
<i>Procedure:</i>						
College Board test program	479	472	392	345	579	402
Advanced Standing Examinations	36	53	36	48	14	53
College transcript	63	58	61	56	96	76
Total	523*	528*	434*	398*	689	531

\* In some cases credit was sought and earned through two procedures; duplication is eliminated in the totals.

Subjects credited	Number of semesters credited		
	1966	1967	1968
Chemistry	115	121	18
Physics	11	13	13
Mathematics	367	388	354
Other specified subjects	22	19	4
Elective Credit (six units each)	122	148	136

visiting trips. We also acknowledge thanks to Leonard V. Gallagher, James S. Jones and Daniel T. Langdale, of the Financial Aid Office and Kenneth C. Browning, Peter Büttner and Richard A. Sorenson of the Dean's Office for taking time out from very busy schedules to visit secondary schools.

The Thirteenth Annual Guidance Conference was held from September 29 to October 1, with Peter D. Leavitt and Julia C. McLellan of the Admissions Office in charge of arrangements. This practice of bringing key members of the guidance profession to the Institute to obtain first-hand information about M.I.T. and admissions policies and procedures, continues to be a very effective means of two-way communication.

The dynamics of change at M.I.T. pose difficult problems for the Admissions staff. We must interpret to potential students and their advisors, from one to three years in advance of matriculation, the quality and personality of, as well as facts about, the Institute they may choose to attend. Usually their impressions are based on outdated reports of what M.I.T. is like. At best, many aspects of M.I.T., about which they are vitally concerned, change so fast that we are constantly challenged to explain what M.I.T. *will be*, rather than merely to elaborate on the present status. Thus, the Admissions Office accepts, as one of its greatest responsibilities, keeping *au courant* with what is taking place, in fact and in prospect, throughout this highly complex community. We greatly appreciate the assistance of both faculty and students in this relatively inconspicuous part of our work, and solicit further help from any and all sources.

ROLAND B. GREELEY

### THE EDUCATIONAL COUNCIL

The Educational Council has grown about 6 per cent to 955 members. At the same time there has been a parallel growth in the spirit and sense of personal involvement on the part of the members of the Educational Council. Major administrative efforts have continued along the lines of improving the performance of the Council and enabling them to be of increasing service to the secondary schools.



The growth, both in size and activity, of the Council poses real challenges. The increasing personal involvement of the members has resulted in a desire on their part to be better informed. Educational Council Members seek information of an immediate nature which would be of value to the students they see, their secondary schools, and in understanding the many on-campus events during this active year. They also want to know what M.I.T. is becoming and how they can relate these long-term changes to the public, especially the secondary schools, and to their own image of M.I.T.

Our efforts have centered on improving the quality and scope of communications with the members of the Council, increasing their ability to be of service to the secondary schools, evolving a more active role for the Council Member in the Admissions and Financial Aid processes, and strengthening local group management. The new Educational Council Handbook has been updated. Extensive attempts have been made to communicate about current campus concerns.

Staff visits were made to 78 of the nearly 100 organized groups of the Council in the past year. During many visits, joint meetings of the local high school guidance personnel and members of the Educational Council were held, enabling a more effective use of staff time. A significant step was achieved through the production of the film, "M.I.T.: Progressions" by David Espar. The film portrays primarily the current aspects of informal, nonclassroom life at M.I.T., which are poorly understood by our applicants, the secondary schools, and many of our alumni. The film was a cooperative effort in which the Office of Public Relations, the Admissions Office, our staff, and many other interested faculty, students, and administration participated.

In order to provide additional services to the secondary schools, through the cooperation of faculty members and the Admissions Office, arrangements were made for six faculty members to visit local communities as Faculty Lecturers. This program, in addition to the Admissions Office regular school visiting program, was arranged by local Educational Council groups. Professors Dwight M. B. Baumann, Secor D. Browne, Charles K. Crawford, Sanford A. Miller, Philip Morrison, and Bernhardt J. Wuensch participated in this active form of curriculum supplement. They spoke to audiences of high school students ranging in size from 50 to several hundred at a time; during their six trips they spoke with well over 12,000 high school students. In addition, our expanded library of M.I.T. Science Reporter Films has been widely circulated to secondary schools by members of the Council.

Continued emphasis has been placed on enlarging the role of the Council members throughout the Admissions and Financial Aid processes. We

have sought to provide additional information to the Council members concerning their applicants, as well as to encourage repeated contact on the part of students with their Educational Counselors. Many individual Council members and several regional organizations have begun to take active and productive roles in helping the Admissions Office seek out black and other disadvantaged applicants.

In order to achieve these objectives, with an enlarged group of more active Council members, we have worked at strengthening the local management of the Council. A new Guide for Regional Chairmen has been prepared. Many of the activities itemized have depended heavily on the ability of local Council groups to organize and perform more active roles. Certainly, as time passes, we will have to make increased demands upon the organized regions within the Council to manage a larger share of the public contact, though we maintain policy control in Cambridge.

In closing, I would like to pay particular tribute to William H. McTigue, former Director of the Educational Council. Many of the programs and ideas of the Council, as well as much of the effort that contributed to their success are owed to him. The Council faces even greater challenges ahead in working with the rising expectations of our students and applicants, and in communicating the changing nature of M.I.T., so that we continue to obtain those young men and women who can best profit from our education.

WILLIAM J. HECHT

### **FOREIGN STUDENT OFFICE**

The complex role of the American colleges and universities as instruments for change in the social order continues in a state of crisis. These institutes, confronted by substantial domestic issues demanding a high priority, are finding it increasingly difficult to maintain an effective international dimension within their educational programs. As a nation, there is, perhaps, a growing tendency, while setting our own house in order, to turn our backs on the outside world. As an example, the International Education Act of 1966 is still without a major appropriation from Congress. This Act was designed to strengthen a broad range of programs in the field of international education for Americans in our colleges and universities. Further, the Fulbright-Hayes program, which has achieved such worldwide acclaim in its twenty-year history, along with many other educational and cultural exchange activities of the Department of State, continues to face unprecedented reductions in funds. Foundations, too, with their considerable resources, are turning to the domestic scene at the expense of their former interests in international education.

FOREIGN STUDENT OFFICE

Despite these shifting priorities, international education has a contribution to make, not only in increased understanding among nations, but to the development of nations and to the sharing of skills and ideas. Thus, the response of American institutions of higher learning to the pressures of events over the next several years will have a profound effect on the direction to be taken in international education in the decades ahead.

The universities and colleges in the Boston-Cambridge community continue to attract students from many nations to their respective campuses. In the 1968 edition of *OPEN DOORS*, a publication of the Institute of International Education, it is stated that Harvard University, Boston University, and M.I.T. account for over 2,800 foreign students of the slightly over 5,000 registered in the state of Massachusetts. With a foreign student enrollment of 4.7 per cent, Massachusetts ranks fifth in the nation. It is preceded only by California (with 16,000 or 16.5 per cent), New York (with 15,000 or 14.5 per cent), Michigan (with 7,000 or 6 per cent) and Illinois (with 6,000 or 5.5 per cent).

**FOREIGN STUDENT PROFILE**

The 1968-69 profile of foreign students at M.I.T. indicates that it will probably rank second among institutions in the United States with the highest enrollment of noncitizens. The foreign population now numbers 1,155 (or 15.8 per cent of the total student population of 7,304), representing eighty-four nations and political entities. Fifty-six are women students. Again, the largest nationality group is from Canada (150), followed by India (102), China (102), and Hong Kong (67). The countries of the Far East represented the largest segment of this population (388), with Europe (292), North America (150), Latin America (141), the Near and Middle East (115), Africa and Oceania (61) following in that order. Eight students were listed as "stateless."

The graduate schools registered 858 foreign citizens, 24.9 per cent of their total population of 3,433. Foreign undergraduates numbered 297 or 7.6 per cent of their total population of 3,861. It should also be noted that 331 foreign students were accompanied by their spouses.

Listed below are other dimensions of the foreign student population.

Degree objectives of Foreign students at M.I.T.	
Bachelor of Science	292
Master of Science	158
Engineer	24
Doctor of Philosophy	466
Doctor of Science	127
Bachelor of Architecture	5
Special Students: Graduate	77
Undergraduate	6
Total	1,155

VICE PRESIDENT, ACADEMIC ADMINISTRATION

School and department enrollment	
Undesignated	77
Architecture & Planning	64
Engineering	567
Humanities & Social Science	79
Management	101
Science	267
Totals	1,155

**FINANCIAL SUPPORT**

Requests for full or partial financial support are reflected in nearly all correspondence received from foreign students seeking admission to M.I.T. Restrictive policies by various governments on the convertibility of local currencies into dollars continues to make it impossible for students, particularly undergraduates, to export funds to the United States to meet their educational costs. M.I.T., therefore, shoulders an important commitment to international education in providing financial support to this student population.

There are 545 graduate and 110 undergraduate students, or 55 per cent of the foreign population, receiving aid in one form or another from M.I.T. This does not include those students who are working part time at M.I.T. or who have borrowed from our loan fund, unless they are also receiving other M.I.T. aid. M.I.T. provides the principal source of support for 552 students. There are 375 (or 32 per cent) students financed principally by their own or family funds (including employment and loans) while a total of 559 are receiving some support from personal sources.

Foreign governments support, in whole or in part, 94 (8.1 per cent) students. The United States Government, through a variety of agencies and programs, contributes to the support of 43 (3.7 per cent) students. Fulbright grantees awarded roundtrip travel grants under this program number 46. Foundations in the United States assist 61 (5.3 per cent) students, and foreign foundations support 83 (7.3 per cent) students. Seven hundred ninety students receive substantial financial assistance from United States based sources, while 194 receive assistance from foreign or international sources.

**FOREIGN FRESHMEN**

M.I.T. continues to attract a small but very able segment of secondary school students abroad, particularly from areas that lack excellent scientific and technological universities, or have too few places in existing universities.

For September 1968, 237 completed applications were received, 57 were offered admission, 42 accepted the offer and registered. Of those coming, 18 were from the Far East, seven from Europe, eight from Latin

America, and nine from the Middle East. They received financial support from the following sources: family—31; own funds and government—one; M.I.T. scholarship, loan and own funds—ten.

The foreign applicants are intercompared and selected by a process which is essentially similar to that used for American secondary school students. The relevant factors are secondary school grades, position in class, teachers' evaluations, College Board scores and nonacademic activities. A special test of English as a Foreign Language is also required.

#### FOREIGN COLLEGE TRANSFERS

A total of 197 foreign students applied for admission with advanced standing for the fall term 1968-69. This represents an increase of 86 over the number of applicants the preceding year. Thirty-three were offered admission and 25 registered. More than half of the registered students originated in the Far East, with Hong Kong providing eight and India six. Six students came from northern Europe and three from Latin American countries.

As was the case last year, the majority of the registered group was entirely self- or family-supported. M.I.T. supported eight with a combination of loans and scholarships. The others were funded from sources other than family within their own countries.

The admission of foreign college transfers is highly competitive, and students are carefully selected on the basis of previous academic record, CEEB achievement scores, endorsements, and when possible, personal interviews. The expectation is that these students will perform well at M.I.T., and they do. Approximately one-third had second-term records of 4.5 or better, and more than half had at least a 4.0. However, there is a negative aspect to such a selective admissions policy. Only children of the upper socio-economic classes who have had exceptional educational opportunities in their homelands or abroad and have had a considerable exposure to the English language have a relatively good chance for admission. Thought should be given as to how M.I.T. may be of assistance to the "underprivileged" foreign student applicant, both transfer and freshman, with a view toward exploring the possibility of establishing a Project Interphase type of program for a selected number of such students. The Latin American Scholarship Program of American Universities (LASPAU), described in last year's annual report, attempts to partially meet this problem by identifying needy but capable students in Latin American universities, who will become college level teachers after completion of a study program in the U.S. During the past year, we had three LASPAU students at M.I.T., but none have been admitted for the coming year.

**THE M.I.T. HOST FAMILY PROGRAM**

“It is important that the student who comes from abroad should feel a warm and friendly welcome here in the United States, and that he be helped as soon as possible to overcome whatever may be barriers to a successful experience. This is important for the student personally and for M.I.T. and for good international relations.”

This paragraph, written by Mrs. Norman J. Padelford, chairman since 1961, as part of an introductory statement to prospective host families, best illustrates the guiding philosophy of this important program.

During the year, nearly 340 families representing alumni, staff, and friends of M.I.T., participated in this program. Collectively, they offered hospitality and friendship to about 530 foreign students.

Leadership in this activity continues to be largely voluntary, and its success is due in no small measure to the able assistance given to the chairman by Mrs. Sidney B. Williams, Mrs. Glenn A. Eichenseer, and Mrs. Nolan T. Jones. Substantial help is also given to the program by Mrs. Roy F. Schwitters, receptionist in the office of the Adviser to Foreign Students.

**THE M.I.T. INTERNATIONAL STUDENT COUNCIL**

Under the leadership of Tat-Wai Tan (Malaysia), Luis M. Homez (Venezuela) and Mohammed A. Bakr (Saudi Arabia), the International Student Council sponsored activities of community interest. A particularly colorful and successful program was International Week, jointly sponsored with the Technology Dames, featuring a Chinese Opera.

**OPERATIONS**

Eugene R. Chamberlain, Adviser to Foreign Students, started a one-year term as President of the National Association for Foreign Student Affairs (N.A.F.S.A.) in April 1969. N.A.F.S.A. is a professional association for those whose work is with people and programs in international educational exchange in all of its aspects, foreign student advisers, Fulbright Program advisers, members of university international offices, teachers of English as a second language, admissions officers, those serving in community programs for foreign students, and those who have responsibility for educational exchange activities in government and private agencies and in business enterprises. Its membership numbers about 1,800, including 680 academic institutional members.

Dr. Robert A. Schuiteman, Associate Adviser to Foreign Students, is a member of the Government Liaison Committee of N.A.F.S.A. During the year, he was chosen as a chief resource person on Colombia for a workshop on the admission and placement of students from Latin America, which was held at the University of Puerto Rico in December 1967.

**FOREIGN STUDENT OFFICE**

In addition to the normal activities of this office, in the admissions and counseling of foreign students, the Adviser wishes to acknowledge the substantial assistance that was given by his associate, Peter D. Leavitt, and the secretarial staff of the office in the management of the Annual Conference of the National Association for Foreign Student Affairs held in Boston in April 1969.

**EUGENE R. CHAMBERLAIN**

**REGISTRAR**

All statistics on registration and staff in the following tables are given as of the fifth week of the Fall Term, except: 1943-44 as of August 2, 1943; 1944-45 as of November 27, 1944; and 1945-46 as of July 30, 1945. For statistics not listed in the following pages, see the report of the Registrar for 1958-59.

**Table I. Student Registration since the Founding of the Institute\***

Year	Number of students	Year	Number of students	Year	Number of students
1865-66	72	1900-01	1,277	1935-36	2,540
1866-67	137	1901-02	1,415	1936-37	2,793
1867-68	167	1902-03	1,608	1937-38	2,966
1868-69	172	1903-04	1,528	1938-39	3,093
1869-70	206	1904-05	1,561	1939-40	3,100
1870-71	224	1905-06	1,466	1940-41	3,138
1871-72	261	1906-07	1,397	1941-42	3,055
1872-73	348	1907-08	1,415	1942-43	3,048
1873-74	276	1908-09	1,461	1943-44	1,579
1874-75	248	1909-10	1,479	1944-45	1,198
1875-76	255	1910-11	1,506	1945-46	1,538
1876-77	215	1911-12	1,559	1946-47	5,172
1877-78	194	1912-13	1,611	1947-48	5,662
1878-79	188	1913-14	1,685	1948-49	5,433
1879-80	203	1914-15	1,816	1949-50	5,458
1880-81	253	1915-16	1,900	1950-51	5,171
1881-82	302	1916-17	1,957	1951-52	4,874
1882-83	368	1917-18	1,698	1952-53	5,074
1883-84	443	1918-19	1,819	1953-54	5,183
1884-85	579	1919-20	3,078	1954-55	5,348
1885-86	609	1920-21	3,436	1955-56	5,648
1886-87	637	1921-22	3,505	1956-57	6,000
1887-88	720	1922-23	3,180	1957-58	6,179
1888-89	827	1923-24	2,949	1958-59	6,259
1889-90	909	1924-25	2,938	1959-60	6,270
1890-91	937	1925-26	2,813	1960-61	6,289
1891-92	1,011	1926-27	2,671	1961-62	6,454
1892-93	1,060	1927-28	2,712	1962-63	6,695
1893-94	1,157	1928-29	2,868	1963-64	6,925
1894-95	1,183	1929-30	3,066	1964-65	7,151
1895-96	1,187	1930-31	3,209	1965-66	7,408
1896-97	1,198	1931-32	3,188	1966-67	7,567
1897-98	1,198	1932-33	2,831	1967-68	7,730
1898-99	1,171	1933-34	2,606	1968-69	7,764
1899-00	1,178	1934-35	2,507		

\* From 1943 to 1946 Army and Navy students are omitted (see Table 3-B in reports for 1943 to 1946).



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**Table I-A Student Registration in the Summer Session since 1948**

Year	*In Regular Subjects	†In Other Subjects	Year	*In Regular Subjects	†In Other Subjects
1948	2,146	—	1959	1,635	1,510
1949	1,875	171	1960	1,600	1,696
1950	1,852	259	1961	1,668	1,412
1951	1,861	813	1962	1,748	1,763
1952	1,689	832	1963	1,808	1,397
1953	1,672	1,289	1964	1,882	1,492
1954	1,675	1,398	1965	2,090	1,568
1955	1,619	1,653	1966	2,054	1,787
1956	1,553	2,497	1967	2,218	1,829
1957	1,548	1,757	1968	2,490	1,842
1958	1,650	1,752			

\* Students attending regular subjects from M.I.T. curricula.

† Students attending professional and technical subjects which are not part of M.I.T. curricula and in general carry no academic credit.

Table II. The Academic Staff\*

	Professors	Administration also Professors	Associate Professors	Assistant Professors	Lecturers	Instructors	Technical Instructors	Research Associates	Research Assistants	Teaching Assistants	Technical Assistants	Total	Professors Emeriti	Others <sup>1</sup>
<b>School of Architecture and Planning</b>														
Architecture	8	2	13	10	2	6	1	5	6	1	—	54	3	5
City and Regional Planning	6	2	3	4	7	4	—	—	9	8	—	43	—	—
<b>Total</b>	<b>14</b>	<b>4</b>	<b>16</b>	<b>14</b>	<b>9</b>	<b>10</b>	<b>1</b>	<b>5</b>	<b>15</b>	<b>9</b>	<b>—</b>	<b>97</b>	<b>3</b>	<b>5</b>
<b>School of Engineering</b>														
Aeronautics and Astronautics	22	2	12	14	6	—	2	3	78	6	—	145	3	2
Chemical Engineering	12	2	4	11	—	4	2	2	33	28	—	98	4	2
Civil Engineering	10	1	16	18	6	11	1	8	96	11	1	179	2	9
Electrical Engineering	47	4	27	45	21	17	—	6	120	101	1	389	6	14
Mechanical Engineering	22	2	22	18	3	5	4	6	118	5	—	205	9	5
Metallurgy and Materials Science	15	2	7	8	1	1	2	4	95	12	—	147	4	10
Naval Architecture and Marine Engineering	7	1	4	4	2	3	—	1	13	8	—	43	2	1
Nuclear Engineering	7	1	7	4	2	1	—	4	33	17	—	76	—	3
School Professors	2	—	—	—	—	—	—	—	—	—	—	2	—	—
<b>Total</b>	<b>144</b>	<b>15</b>	<b>99</b>	<b>122</b>	<b>41</b>	<b>42</b>	<b>11</b>	<b>34</b>	<b>586</b>	<b>188</b>	<b>2</b>	<b>1,284</b>	<b>30</b>	<b>46</b>
<b>School of Humanities and Social Science</b>														
Economics	13	2	3	7	—	8	—	—	5	11	—	49	2	5
Humanities	21	1	19	18	10	17	—	1	1	2	—	90	1	1
Modern Languages and Linguistics	4	2	3	3	2	15	—	1	7	2	—	39	3	6
Political Science	17	1	5	10	8	5	—	—	7	4	—	57	—	1
Psychology	2	1	4	3	—	1	—	8	2	4	—	25	—	4
<b>Total</b>	<b>57</b>	<b>7</b>	<b>34</b>	<b>41</b>	<b>20</b>	<b>46</b>	<b>—</b>	<b>10</b>	<b>22</b>	<b>23</b>	<b>—</b>	<b>260</b>	<b>6</b>	<b>17</b>
<b>Alfred P. Sloan School of Management</b>														
Management	22	2	10	25	13	8	—	7	33	32	—	152	2	6

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School of Science	13	2	8	6	4	35	6	12	34	120	1	28		
Biology	20	2	8	8	2	54	91	85	12	282	12	18		
Chemistry	9	1	4	7	—	12	39	10	—	82	2	1		
Geology and Geophysics	33	1	11	10	6	3	10	40	—	147	3	2		
Mathematics	7	2	3	2	—	3	41	2	1	61	1	1		
Meteorology	9	2	11	9	14	2	25	32	1	127	—	8		
Nutrition and Food Science	56	1	15	32	5	8	1	2	143	322	1	36		
<b>Total</b>	<b>147</b>	<b>11</b>	<b>60</b>	<b>74</b>	<b>27</b>	<b>47</b>	<b>1</b>	<b>134</b>	<b>362</b>	<b>207</b>	<b>71</b>	<b>1141</b>	<b>20</b>	<b>94</b>
Miscellaneous	—	1	1	—	—	2	—	—	—	4	—	—		
Aerospace Studies	—	1	5	4	—	8	—	—	—	18	—	—		
Athletic	—	2	—	—	—	—	—	—	—	2	—	—		
Medical	—	1	4	1	—	2	—	—	—	8	—	—		
Military Science	—	1	1	1	—	4	—	—	—	7	—	—		
Naval Science	16	1	—	—	—	—	—	—	—	18	1	—		
Institute Professors <sup>2</sup>	4	—	—	—	—	—	—	—	—	4	3	—		
Administration	—	—	—	—	—	—	—	—	—	1	—	—		
Center for International Studies	—	—	—	—	—	—	—	—	—	—	—	—		
Center for Materials Science and Engineering	—	—	—	—	—	—	1	—	—	—	—	7		
Center for Space Research	—	—	—	—	—	—	—	—	—	—	—	3		
Laboratory for Nuclear Science	—	—	—	—	—	—	—	—	—	—	—	5		
National Magnet Laboratory	—	—	—	—	—	—	—	—	—	—	—	4		
Operations Research Center	—	—	—	—	—	—	—	—	—	—	—	1		
Research Laboratory of Electronics	—	—	—	—	—	—	—	—	—	1	—	—		
<b>Total</b>	<b>20</b>	<b>7</b>	<b>11</b>	<b>6</b>	<b>1</b>	<b>16</b>	<b>—</b>	<b>2</b>	<b>—</b>	<b>63</b>	<b>4</b>	<b>58</b>		
<b>Grand Total</b>	<b>404<sup>3</sup></b>	<b>46<sup>3</sup></b>	<b>230<sup>3</sup></b>	<b>282<sup>3</sup></b>	<b>111<sup>3</sup></b>	<b>169<sup>3</sup></b>	<b>13<sup>3</sup></b>	<b>192<sup>3</sup></b>	<b>1018</b>	<b>459<sup>3</sup></b>	<b>73</b>	<b>2,997</b>	<b>65<sup>5</sup></b>	<b>226<sup>5</sup></b>
Faculty ex-officio	—	—	—	—	—	—	—	—	—	—	—	—	—	27 <sup>6</sup>
														<b>3,024</b>

\* Full professors, associate professors, and assistant professors include 30 professors, 2 associate professors, and 1 assistant professor emeriti part-time active. The total faculty is 990.  
<sup>1</sup> Includes guests, visiting scientists, visiting social scientists, research affiliates, postdoctoral associates, and fellows.  
<sup>2</sup> Includes Institute lecturers.  
<sup>3</sup> Total teaching staff is 1714.  
<sup>4</sup> One faculty and 191 non-faculty.  
<sup>5</sup> Not included in preceding total.  
<sup>6</sup> Includes one emeriti part-time active.

Table III. Classification of students since 1966

Course	1966-67				1967-68				1968-69				Course Number			
	2	3	4	G Total	2	3	4	G Total	2	3	4	G Total				
<b>School of Architecture and Planning</b>																
Architecture (IV)	—	—	—	—	21	—	—	93	114	40	27	6	82	155	IV	
Architecture (IV-A)	25	26	26	62	139	—	16	19	35	—	—	8	—	8	IV-A	
Fifth year	—	—	24	24	24	—	26	—	26	—	—	20	—	20		
City and Regional Planning (XI) <sup>1</sup>	—	—	—	73	73	—	—	88	88	—	—	—	112	112	XI	
<b>Total</b>	<b>25</b>	<b>26</b>	<b>50</b>	<b>135</b>	<b>236</b>	<b>21</b>	<b>16</b>	<b>45</b>	<b>263</b>	<b>40</b>	<b>27</b>	<b>34</b>	<b>194</b>	<b>295</b>	<b>Total</b>	
<b>School of Engineering</b>																
Aeronautics and Astronautics (XVI)	82	72	52	248	454	65	80	71	252	468	59	60	73	226	418	XVI
Aeronautics and Astronautics (XVI-B) (Cooperative)	—	10	11	—	21	—	—	9	—	9	—	15	4	—	19	XVI-B
Chemical Engineering (X, X-A, X-B)	37	33	39	144	253	32	34	34	139	239	27	35	36	117	215	X, X-A, X-B
Civil Engineering (I)	19	30	32	216	297	20	23	30	211	284	16	30	22	191	259	I
Electrical Engineering (VI-1)	154	126	136	528	1,092	146	135	142	559	1,129	36	39	52	543	1,159	VI
Electrical Science and Engineering (VI-2)	64	43	41	228	312	54	51	42	201	312	—	38	49	40	127	VI-A
Electrical Engineering (VI-A) (Cooperative)	—	44	34	22	100	—	48	45	20	113	—	—	—	—	40	VI-A
Mechanical Engineering (II)	53	46	63	233	395	46	66	51	249	412	41	60	63	246	410	II
Textile Technology	—	—	—	16	16	—	—	—	13	13	—	—	—	14	14	II-T
Mechanical Engineering (II-B) (Cooperative)	—	5	8	—	13	—	2	6	—	8	—	—	3	—	3	II-B
Metallurgy (III-A)	—	5	11	141	209	16	25	15	147	227	—	—	—	—	—	III
Materials Science (III-B)	16	11	6	19	32	—	—	—	24	—	—	—	—	—	—	III
Ceramics	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Metallurgy and Materials Science (III)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Naval Architecture and Marine Engineering (XIII)	7	5	12	45	69	5	6	8	65	84	6	4	9	66	85	XIII
Naval Construction and Engineering (XIII-A)	—	—	—	70	70#	—	—	—	84	84#	—	—	—	78	78	XIII-A
Nuclear Engineering (XXII)	—	—	—	128	128	—	—	—	137	137	—	—	—	130	130	XXII
Shipping and Shipbuilding Management (XIII-B)	—	—	—	5	5	—	—	—	2	2	—	—	—	1	1	XIII-B
Center for Advanced Engineering Study (EN)	—	—	—	13	13	—	—	—	29	29	—	—	—	50	50	EN
<b>Total</b>	<b>432</b>	<b>430</b>	<b>445</b>	<b>1,828</b>	<b>3,135</b>	<b>384</b>	<b>470</b>	<b>453</b>	<b>1,931</b>	<b>3,238</b>	<b>368</b>	<b>467</b>	<b>486</b>	<b>1,871</b>	<b>3,192</b>	<b>Total</b>

**School of Humanities and Social Science**

Economics (XIV)	17	26	25	130	198	13	31	37	121	202	15	25	40	125	205	XIV
Humanities and Engineering (XXI-A)	4	11	20	34	152	12	7	13	26	147	3	14	10	25	194	XXI
Humanities and Science (XXI-B)	14	33	36			8	45	36			32	50	60			
Modern Languages and Linguistics (XXIII)	—	—	—	45	45	—	—	—	34	34	—	—	—	39	39	XXIII
Political Science (XVII)	7	19	35	80	141	7	26	33	90	156	11	23	33	87	154	XVII
Psychology (IX)	—	—	—	26	26	—	—	—	29	29	—	—	—	29	29	IX
<b>Total</b>	<b>42</b>	<b>89</b>	<b>116</b>	<b>315</b>	<b>562</b>	<b>40</b>	<b>109</b>	<b>119</b>	<b>300</b>	<b>568</b>	<b>61</b>	<b>112</b>	<b>143</b>	<b>305</b>	<b>621</b>	<b>Total</b>

**Alfred P. Sloan School of Management**

Management (XV) <sup>2</sup>	25	43	70	348	486	31	59	62	344	496	23	51	72	353	499	XV
<b>School of Science</b>																
Biology (VII)	47	44	37	127	255	37	51	48	115	251	47	49	44	115	255	VII
Chemistry (V)	55	32	44	261	392	31	39	35	286	391	27	24	44	295	390	V
Geology and Geophysics (XII)	10	18	12	73	113	10	11	18	83	122	9	10	14	87	120	XII
Geology and Geophysics (XII-A)	—	—	—	2	2	—	—	—	1	1	—	—	—	3	3	XII-A
Physical Sciences (XII-B)	—	—	—	—	—	—	—	—	—	—	10	5	1	—	16	XII-B
Mathematics (XVIII)	85	103	115	141	444	107	93	99	145	444	75	101	92	134	402	XVIII
Meteorology (XIX)	—	—	—	68	68	—	—	—	62	62	—	—	—	69	69	XIX
Nutrition and Food Science (XX)	—	—	—	110	110	—	—	—	101	101	—	—	—	93	93	XX
Physics (VIII)	132	129	129	302	692	111	125	114	324	674	142	115	118	290	665	VIII
<b>Total</b>	<b>329</b>	<b>326</b>	<b>337</b>	<b>1,084</b>	<b>2,076</b>	<b>296</b>	<b>319</b>	<b>314</b>	<b>1,117</b>	<b>2,046</b>	<b>310</b>	<b>304</b>	<b>313</b>	<b>1,086</b>	<b>2,013</b>	<b>Total</b>
Undesignated	137	—	—	—	137	191	—	—	—	191	171	—	—	—	171	Undesignated
First-year students	935	—	—	—	935	928	—	—	—	928	973	—	—	—	973	First-year
<b>Grand Total</b>	<b>935</b>	<b>990</b>	<b>914</b>	<b>1,018*</b>	<b>3,710</b>	<b>928</b>	<b>963</b>	<b>973</b>	<b>993*</b>	<b>3,873</b>	<b>973</b>	<b>961</b>	<b>1,048*</b>	<b>3,809</b>	<b>7,764</b>	<b>Grand total</b>

#First graduate year — 25 #First graduate year — 35  
 Second graduate year — 30 Second graduate year — 24  
 Third graduate year — 15 Third graduate year — 25

\* These totals include the fifth year in Architecture.  
 1 Prior to 1966-67 Course IV-B.  
 2 Prior to 1966-67 Industrial Management.

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**Table III-A. Women Students Classified by Schools, Courses, and Years, 1968-69<sup>1</sup>**

Course	Year			G Total	
	2	3	4		
<b>School of Architecture and Planning</b>					
Architecture (IV)	5	2	—	18	} 26
Architecture (IV-A)	—	—	1	—	
Fifth Year	—	—	—	—	
City and Regional Planning (XI)	—	—	—	26	<b>26</b>
<b>Total</b>	<b>5</b>	<b>2</b>	<b>1</b>	<b>44</b>	<b>52</b>
<b>School of Engineering</b>					
Aeronautics and Astronautics (XVI)	—	—	—	—	—
Chemical Engineering (X)	2	1	3	—	<b>6</b>
Civil Engineering (I)	2	1	—	2	<b>5</b>
Electrical Engineering (VI)	7	6	3	7	<b>23</b>
Mechanical Engineering (II)	1	2	—	4	<b>7</b>
Metallurgy and Materials Science (III)	1	—	4	3	<b>8</b>
Naval Architecture and Marine Engineering (XIII)	—	—	—	1	<b>1</b>
Nuclear Engineering (XXII)	—	—	—	1	<b>1</b>
<b>Total</b>	<b>13</b>	<b>10</b>	<b>10</b>	<b>18</b>	<b>51</b>
<b>School of Humanities and Social Science</b>					
Economics (XIV)	3	4	2	14	<b>23</b>
Humanities and Engineering or Science (XXI-A, XXI-B)	7	12	5	5	<b>29</b>
Modern Languages and Linguistics (XXIII)	—	—	—	12	<b>12</b>
Political Science (XVII)	2	—	3	15	<b>20</b>
Psychology (IX)	—	—	—	6	<b>6</b>
<b>Total</b>	<b>12</b>	<b>16</b>	<b>10</b>	<b>52</b>	<b>90</b>
<b>Alfred P. Sloan School of Management</b>					
Management (XV)	—	1	1	14	<b>16</b>
<b>School of Science</b>					
Biology (VII)	5	4	6	29	<b>44</b>
Chemistry (V)	3	2	6	28	<b>39</b>
Geology and Geophysics (XII)	1	1	2	3	<b>7</b>
Mathematics (XVIII)	12	11	10	9	<b>42</b>
Meteorology (XIX)	—	—	—	—	—
Nutrition and Food Science (XX)	—	—	—	20	<b>20</b>
Physics (VIII)	4	3	4	10	<b>21</b>
<b>Total</b>	<b>25</b>	<b>21</b>	<b>28</b>	<b>99</b>	<b>173</b>
Undesignated	11	—	—	—	<b>11</b>
First-year students	65	—	—	—	<b>65</b>
<b>Grand Total</b>	<b>65</b>	<b>66</b>	<b>50</b>	<b>50</b>	<b>227</b>

<sup>1</sup> Included also in Table 3

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Table III-B. Special Students Classified by Schools, Courses, and Years, 1968-69<sup>1</sup>

Course	Year			G Total	Total
	2	3	4		
<b>School of Architecture and Planning</b>					
Architecture (IV)	3	4	—	17	24
Architecture (IV-A)					
Fifth Year	—	—	1	—	1
City and Regional Planning (XI)	—	—	—	33	33
<b>Total</b>	<b>3</b>	<b>4</b>	<b>1</b>	<b>50</b>	<b>58</b>
<b>School of Engineering</b>					
Aeronautics and Astronautics (XVI)	—	1	—	69	70
Chemical Engineering (X)	—	1	—	2	3
Civil Engineering (I)	1	1	—	12	14
Electrical Engineering (VI)	3	3	2	146	154
Mechanical Engineering (II)	—	1	—	20	21
Metallurgy and Materials Science (III)	—	—	—	13	13
Naval Architecture and Marine Engineering (XIII)	—	—	—	15	15
Nuclear Engineering (XXII)	—	—	—	3	3
Center for Advanced Engineering Study (EN)	—	—	—	50	50
<b>Total</b>	<b>4</b>	<b>7</b>	<b>2</b>	<b>330</b>	<b>343</b>
<b>School of Humanities and Social Science</b>					
Economics (XIV)	1	—	—	7	8
Humanities and Engineering or Science (XXI-A, XXI-B)	3	6	1	4	14
Modern Languages and Linguistics (XXIII)	—	—	—	5	5
Political Science (XVII)	—	1	—	19	20
Psychology (IX)	—	—	—	4	4
<b>Total</b>	<b>4</b>	<b>7</b>	<b>1</b>	<b>39</b>	<b>51</b>
<b>Alfred P. Sloan School of Management</b>					
Management (XV)	1	1	—	44	46
<b>School of Science</b>					
Biology (VII)	—	—	1	15	16
Chemistry (V)	—	—	—	6	6
Geology and Geophysics (XII)	—	—	—	4	4
Mathematics (XVIII)	1	2	1	16	20
Meteorology (XIX)	—	—	—	4	4
Nutrition and Food Science (XX)	—	—	—	10	10
Physics (VIII)	—	2	—	17	19
<b>Total</b>	<b>1</b>	<b>4</b>	<b>2</b>	<b>72</b>	<b>79</b>
Undesignated		2	—	—	2
First-year students	4	—	—	—	4
<b>Grand Total</b>	<b>4</b>	<b>15</b>	<b>23</b>	<b>6</b>	<b>535</b>
				<b>583</b>	

<sup>1</sup> Included also in Table 3.

**Table IV. Continued, Former, and New Students**

	1964-65	1965-66	1966-67	1967-68	1968-69
<b>Continued Students</b>					
Undergraduate and graduate students registered at the end of the last academic year (including Special Students)	4,871	5,041	5,201	5,368	5,426
<b>Non-continued Students</b>					
Former undergraduate and graduate students who previously attended the Institute but were not registered at the end of the last academic year (including Special Students)	320	333	264	225	260
Undergraduate students who enrolled for the first time since secondary school (excluding Special Students)	887	953	922	912	963
Undergraduate students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding Special Students)	67	54	71	75	85
Graduate students who enrolled for the first time at the Institute (excluding Special Students)	817	820	840	890	756
Special Undergraduate and Graduate Students with no previous Institute registration	189	207	269	260	274
<b>Total</b>	<b>7,151</b>	<b>7,408</b>	<b>7,567</b>	<b>7,730</b>	<b>7,764</b>



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**Table V. Regular Students from Other Colleges and Graduates of M.I.T. Classified by Schools and Courses, 1968-1969**

	Entered with no previous degree	Entered with Bachelor's degree from other colleges	Entered Graduate School with Bachelor's degree from M.I.T.	
<b>School of Architecture and Planning</b>		Under-graduate	Graduate	
Architecture (IV-A)	21	11	57	8
City and Regional Planning (XI)	—	—	69	10
<b>Total</b>	<b>21</b>	<b>11</b>	<b>126</b>	<b>18</b>
<b>School of Engineering</b>				
Aeronautics and Astronautics (XVI)	11	—	106	51
Chemical Engineering (X)	10	—	88	27
Civil Engineering (I)	11	—	143	36
Electrical Engineering (VI-1, VI-2, VI-A)	62	1	208	229
Mechanical Engineering (II, II-T)	14	1	180	60
Metallurgy and Materials Science (III)	1	—	108	48
Naval Architecture and Marine Engineering (XIII)	6	—	40	11
Naval Construction and Engineering (XIII-A)	—	—	76	2
Nuclear Engineering (XXII)	—	—	118	9
Shipping and Shipbuilding Management (XIII-B)	—	—	1	—
<b>Total</b>	<b>115</b>	<b>2</b>	<b>1,068</b>	<b>473</b>
<b>School of Humanities and Social Science</b>				
Economics (XIV)	6	—	111	7
Humanities and Engineering or Science (XXI-A, XXI-B)	2	—	15	6
Modern Languages and Linguistics (XXIII)	—	—	31	3
Political Science (XVII)	3	—	59	9
Psychology (IX)	—	—	21	4
<b>Total</b>	<b>11</b>	<b>—</b>	<b>237</b>	<b>29</b>
<b>Alfred P. Sloan School of Management</b>				
Management (XV)	8	—	246	63
<b>School of Science</b>				
Biology (VII)	5	—	94	6
Chemistry (V)	7	1	289	—
Geology and Geophysics (XII, XII-A)	2	—	70	16
Mathematics (XVIII)	17	—	86	32
Meteorology (XIX)	—	—	59	6
Nutrition and Food Science (XX)	—	—	72	11
Physics (VIII)	40	1	185	88
<b>Total</b>	<b>71</b>	<b>2</b>	<b>855</b>	<b>159</b>
Undesignated	1	—	—	—
First Year	2	—	—	—
<b>Grand Total</b>	<b>229</b>	<b>15</b>	<b>2,532</b>	<b>742</b>

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**Table VI. List of Colleges and Universities with Number of Graduates Entering the Institute as Regular Graduate Students, 1968-69<sup>1</sup>**

United States			
		Harvey Mudd College	2
		Houston, University of	1
		Hunter College	1
		Illinois, University of	4
		Illinois Institute of Technology	1
		Iowa, University of	6
		Johns Hopkins University	3
		Kansas, University of	1
		Kansas State University	1
		Kentucky, University of	2
		Lawrence University	1
		Lehigh University	5
		Lincoln University	1
		Lowell Technological Institute	1
		Loyola University	1
		Macalester College	1
		Maine, University of	1
		Manhattan College	5
		Manhattanville College	2
		Maryland, University of	5
		Massachusetts, University of	1
		Massachusetts Institute of Technology	186
		Miami, University of (Florida)	1
		Miami University (Ohio)	2
		Michigan, University of	8
		Michigan State University	7
		Michigan Technological University	3
		Minnesota, University of	3
		Mississippi, University of	1
		Missouri, University of, at Rolla	2
		Montana State University	1
		Mount Holyoke College	3
		Nebraska, University of	1
		New Mexico, University of	1
		New York Institute of Technology	1
		New York University	7
		North Carolina, University of	5
		Northeastern University	14
		Northwestern University	5
		Norwich University	1
		Notre Dame, University of	3
		Oberlin College	5
		Occidental College	2
		Ohio Northern University	1
		Ohio State University	1
		Oklahoma, University of	2
		Oklahoma State University	1
		Oregon, University of	3
		Oregon State University	2
		Pennsylvania, University of	3
		Pennsylvania State University	8
		Pittsburgh, University of	5
		Polytechnic Institute of Brooklyn	1
		Pomona College	1
		Pratt Institute	1
		Princeton University	14
		Principia College	1
		Puerto Rico, University of	5
		Purdue University	11
		Queens College	4
Air Force Institute of Technology (Ohio)	1		
Alabama, University of	1		
American University	1		
Amherst College	4		
Antioch College	1		
Arizona, University of	1		
Arizona State University	1		
Auburn University	1		
Augustana College	1		
Boston College	3		
Bowdoin College	3		
Brandeis University	4		
Brigham Young University	2		
Brooklyn College	4		
Brown University	2		
Bucknell University	1		
California, University of, at Berkeley	22		
California, University of, at Davis	3		
California, University of, Los Angeles	3		
California, University of, at Riverside	1		
California, University of, at San Diego	2		
California Institute of Technology	4		
California State College at Long Beach	1		
Carleton College	2		
Carnegie-Mellon University	9		
Case Western Reserve University	6		
Catholic University of America	2		
Chicago, University of City College, The	4		
Clarkson College of Technology	11		
Clemson University	2		
Colorado, University of	1		
Colorado School of Mines	2		
Columbia University	1		
Cornell University	12		
Connecticut, University of	4		
Cooper Union	3		
Cornell University	3		
Dartmouth College	16		
Delaware, University of	3		
Denison University (Ohio)	1		
Detroit, University of	1		
Drexel Institute of Technology	4		
Duke University	7		
Fairleigh Dickinson University	1		
Florida, University of	1		
Florida Atlantic University	1		
Florida State University	2		
Fordham University	1		
General Motors Institute	10		
Georgetown University	3		
Georgia Institute of Technology	3		
Goucher College	1		
Grinnell College	1		
Hamline University	1		
Harvard University	15		

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Radcliffe College	7		
Randolph-Macon College	1		
Reed College	1		
Rensselaer Polytechnic Institute	12		
Rice University	4		
Rochester, University of	5		
Rose Polytechnic Institute	1		
Rutgers-The State University	3		
Saint Louis University	1		
San Francisco, University of	1		
San Francisco State College	1		
Seattle University	1		
Simmons College	1		
Smith College	2		
South Dakota School of Mines and Technology	4		
Southern California, University of	4		
Southern Methodist University	1		
Stanford University	5		
State University of New York at Buffalo	1		
State University of New York Maritime College	1		
Steven Institute of Technology	1		
Syracuse University	3		
Tennessee, University of	1		
Texas, University of	3		
Texas Agricultural and Mechanical University	3		
Trinity University	1		
Tufts University	6		
Tulane University	2		
Tuskegee Institute	1		
Union College and University	4		
U. S. Air Force Academy	3		
U. S. Coast Guard Academy	5		
U. S. Military Academy	12		
U. S. Naval Academy	19		
U. S. Naval Postgraduate School	2		
Utah, University of	2		
Vanderbilt University	1		
Vassar College	2		
Vermont, University of	1		
Villanova University	3		
Virginia, University of	3		
Virginia Polytechnic Institute	2		
Wabash College	2		
Washington, University of	8		
Washington State University	1		
Washington University (Missouri)	1		
Wayne State University	2		
Webb Institute of Naval Architecture	1		
Wellesley College	2		
Wesleyan University	2		
William Jewel College	1		
Williams College	3		
Winona State College	1		
Wisconsin, University of	4		
Wisconsin State University	3		
Wooster, College of	1		
Worcester Polytechnic Institute	4		
Yale University	12		
<b>Total</b>	<b>756</b>		
		<b>Foreign</b>	
		Aarhus Universitet (Denmark)	2
		Adelaide, University of (Australia)	1
		Alberta, University of (Canada)	2
		Akademie der Bildenden Kunste (Austria)	1
		American University of Beirut (Lebanon)	1
		Ateneo de Manila (Philippines)	1
		Auckland, University of (New Zealand)	1
		Baghdad, University of (Iraq)	1
		Barcelona, Universidad de (Spain)	2
		Bihar University (India)	1
		Birla Institute of Technology (India)	1
		Bombay, University of (India)	1
		British Columbia, University of (Canada)	3
		Buenos Aires, Universidad de (Argentina)	2
		Calcutta, University of (India)	1
		Canterbury, University of (New Zealand)	1
		Cambridge University (England)	10
		Cape Town University (South Africa)	1
		Chile, Universidad de (Chile)	1
		Chinese Naval Academy (Taiwan)	1
		Christian-Albrechts-Universitat Kiel (Germany)	1
		Chulalongkorn University (Thailand)	2
		Chung Chi College (Hong Kong)	2
		Colombia, Universidad Nacional de (Columbia)	1
		Delhi School of Economics (India)	1
		Ecole Centrale des Arts et Manufactures (France)	7
		Ecole Nationale des Langues Orientales Vivantes (France)	1
		Ecole Nationale des Ponts et Chaussees (France)	1
		Ecole Nationale Superieure de l'Aeronautique (France)	1
		Ecole Nationale Superieure des Mines de Paris (France)	2
		Ecole Nationale Superieure des Industries Chimiques (France)	1
		Ecole Polytechnique (France)	2
		Eidgenossische Technische Hochschule (Switzerland)	2
		Escuela de Ingeniera Naval (Chile)	1
		Essex, University of (England)	1
		Ethnikon Metsovion Polytechnion (Greece)	3
		Genova, Universita di (Italy)	1
		Grenoble, Universite de (France)	1
		Handelshogskolan i Stockholm (Sweden)	1
		Hebrew University (Israel)	4
		Hitotsubashi Daigaku (Japan)	1

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Indian Institute of Technology (Bombay, India)	1	Philippines, University of the (Philippines)	1
Indian Institute of Technology (Coimbatore, India)	1	Politecnico di Milano (Italy)	1
Indian Institute of Technology (Khanpur, India)	5	Queen's University (Canada)	1
Indian Institute of Technology (Madras, India)	2	Queen's University of Belfast (North Ireland)	1
Indian Institute of Technology (New Delhi, India)	1	Rheinisch-Westfalische Technische Hochschule (Germany)	1
Instituto Politecnico Nacional (Mexico)	1	Rijksuniversiteit te Leiden (Netherlands)	1
Istanbul Teknik Okulu (Turkey)	2	Rio de Janeiro, Universidade do (Brazil)	1
Jadavpur University (India)	1	Roorkee, University of (India)	1
Laval University (Canada)	1	Roma, Università di (Italy)	1
Lisbon Naval Academy (Portugal)	2	Simon Fraser University (Canada)	1
London, University of (England)	9	Sir George Williams University (Canada)	1
Los Andes, Universidad de (Colombia)	1	Strasbourg, Université de (France)	1
Maharaja Sayajirao University of Baroda (India)	1	Strathclyde, University of (Scotland)	1
Makerere College (East Africa)	1	Taiwan Provincial Cheng-Kung University (Taiwan)	3
Manitoba, University of (Canada)	4	Technion, The (Israel)	3
Melbourne University (Australia)	1	Technische Hochschule Darmstadt (Germany)	1
McGill University (Canada)	5	Technische Hochschule Munchen (Germany)	1
McMaster University (Canada)	2	Technische Hochschule Stuttgart (Germany)	1
Montreal, Université de (Canada)	2	Technische Universität Berlin (Germany)	1
Mysore University (India)	1	Tokyo Kogyo Daigaku (Japan)	2
Nagoya Daigaku (Japan)	1	Tokyo University (Japan)	6
Nagpur, University of (India)	1	Toronto, University of (Canada)	4
Nancy, Université de (France)	1	Tohoku University (Japan)	2
National Chiao-Tung University (Republic of China)	1	Universidad Nacional Autónoma de Mexico (Mexico)	1
National Taiwan University (Taiwan)	5	Université Catholique de Louvain (Belgium)	2
National Tsinghua University (China)	1	Université de Sarajevo (Yugoslavia)	1
Newcastle-upon-Tyne, University of (England)	1	Victoria University of Manchester (England)	1
Nihon University (Japan)	1	Waseda Daigaku (Japan)	2
Nuevo Leon, Universidad de (Mexico)	1	Western Ontario, University of (Canada)	2
Osaka Daigaku (Japan)	1	<b>Total</b>	<b>186</b>
Orta Dogu Teknik Universitesi (Turkey)	1	<b>Grand Total</b>	<b>942</b>
Oxford University (England)	7		
Panjab, University of the (Pakistan)	1		
Paris, Université de (France)	1		

<sup>1</sup> Graduates of 173 Colleges and Universities in the United States and 104 Foreign Colleges entered the Institute.

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Table VII. Geographic Distribution of Students, 1968-69

	Under-grad.	Grad.	Under-grad.	Grad.	Under-grad.	Grad.		
<b>United States:</b>								
Alabama	17	16	Washington	39	38	Iraq	1	1
Alaska	4	2	West Virginia	12	7	Ireland	0	6
Arizona	10	10	Wisconsin	52	23	Israel	3	29
Arkansas	13	3	Wyoming	4	1	Italy	3	15
California	173	165				Jamaica	0	1
Colorado	37	18	<b>U.S. Territories and Dependences:</b>			Japan	9	42
Connecticut	108	86	Puerto Rico	10	6	Jordan	0	3
Delaware	12	9	U.S. Citizen			Kenya	0	1
District of Columbia	16	23	Foreign Address	32	20	Korea	8	19
Florida	93	46				Kuwait	1	1
Georgia	38	19	<b>Total U.S.</b>	<b>3,641</b>	<b>2,920</b>	Lebanon	0	8
Hawaii	18	2				Malaysia	4	5
Idaho	8	2	<b>Foreign Countries:*</b>			Mexico	4	8
Illinois	187	120	Argentina	2	19	Netherlands	3	12
Indiana	47	39	Australia	1	9	Netherlands Antilles	2	0
Iowa	19	10	Austria	2	4	New Zealand	0	7
Kansas	21	18	Bahama Islands	0	1	Nigeria	3	11
Kentucky	14	8	Belgium	2	11	Norway	8	11
Louisiana	12	18	Brazil	3	16	Pakistan	6	6
Maine	19	18	Bulgaria	0	1	Panama	0	1
Maryland	129	56	Burma	1	0	Peru	3	7
Massachusetts	430	860	Cameroon	0	1	Philippines	3	8
Michigan	74	69	Canada	47	117	Poland	3	3
Minnesota	49	33	Ceylon	0	2	Portugal	0	4
Mississippi	4	5	Chile	0	13	Republic of China	28	75
Missouri	64	21	Colombia	4	8	Rhodesia	2	2
Montana	8	8	Costa Rica	2	0	Rumania	1	1
Nebraska	14	7	Cuba	7	7	Saudi Arabia	3	0
Nevada	3	2	Cyprus	1	1	Scotland	0	4
New Hampshire	23	19	Czechoslovakia	1	0	Sierra Leone	0	1
New Jersey	272	157	Denmark	1	6	Singapore	0	3
New Mexico	15	8	Dominican Republic	2	2	South Africa, Republic of	1	7
New York	772	428	Ecuador	2	0	Spain	1	7
North Carolina	19	20	El Salvador	1	0	Sweden	1	1
North Dakota	1	5	England	14	53	Switzerland	0	13
Ohio	200	112	Ethiopia	0	1	Syria	1	0
Oklahoma	25	20	Finland	1	4	Thailand	4	7
Oregon	26	12	France	4	43	Trinidad	0	1
Pennsylvania	230	155	Germany	2	20	Turkey	7	12
Rhode Island	19	22	Ghana	2	2	Uganda	0	2
South Carolina	15	8	Greece	7	30	United Arab Republic (Egypt)	2	6
South Dakota	11	6	Guatemala	1	1	Uruguay	1	1
Tennessee	26	15	Haiti	1	1	Venezuela	8	12
Texas	92	59	Hong Kong	38	31	Vietnam	0	2
Utah	9	13	Iceland	0	2	Yugoslavia	2	2
Vermont	11	8	India	16	92	Stateless	5	3
Virginia	85	65	Indonesia	0	2	<b>Total Foreign</b>	<b>314</b>	<b>889</b>
			Iran	18	18	<b>Grand Total</b>	<b>3,955</b>	<b>3,809</b>

\* Country of Citizenship

Table VIII. Number of Degrees Awarded in September, 1968, January, 1969, and June, 1969

	S.B.		B. Arch.		S.M.		M. Arch., M. C. P.		Engineer		Ph.D.*		Sc.D.*		Total				
	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June			
<b>School of Architecture and Planning</b>																			
Architecture	—	—	2	1	17	—	—	—	—	—	—	—	—	—	—	—	31	4	18
City and Regional Planning	—	—	—	—	—	—	7	1	7	—	—	3	3	—	—	—	7	4	10
Art and Design	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8
<b>Total</b>	—	8	2	1	17	—	36	4	8	—	—	3	3	—	—	38	8	36	
<b>School of Engineering</b>																			
Aeronautics and Astronautics	3	1	61	—	—	34	8	13	—	—	—	—	—	—	—	—	38	15	83
Ceramics	—	—	—	—	—	—	—	—	—	1	—	3	—	—	—	—	—	—	4
Chemical Engineering	2	1	21	—	—	6	5	16	—	—	1	1	2	3	6	3	13	13	43
Chemical Engineering Practice	—	—	—	—	—	—	4	1	—	—	—	—	—	—	—	—	—	—	4
Civil Engineering	—	16	2	—	—	20	15	14	—	1	3	8	4	5	2	1	3	—	26
Electrical Engineering	27	17	157	—	—	71	35	62	—	10	15	34	12	11	16	2	2	1	122
Materials Engineering	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80
Mechanical Engineering	5	3	30	2	—	23	25	33	—	1	5	8	2	7	7	1	8	12	32
Metallurgy	—	—	—	—	—	7	2	2	—	—	—	—	—	—	—	—	—	—	7
Metallurgy and Materials Science	—	14	—	—	—	—	—	—	—	—	—	8	11	11	3	5	2	11	16
Naval Architecture and Marine Eng.	—	1	6	—	—	8	8	12	—	1	1	27	—	—	—	—	—	9	11
Nuclear Engineering	—	—	—	—	—	7	16	12	—	2	1	3	2	4	4	1	2	1	12
Ocean Engineering	—	—	—	—	—	—	1	2	5	—	—	—	—	—	—	—	—	—	23
Shipping and Shipbuilding Management	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20
Textile Technology	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
<b>Total</b>	37	23	305	4	—	179	121	172	—	17	25	84	29	44	45	11	28	22	273
<b>School of Humanities and Social Science</b>																			
Economics	1	1	33	—	—	3	4	1	—	—	—	8	1	9	—	—	—	—	12
Humanities and Engineering	1	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Humanities and Science	6	2	28	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	6
Linguistics	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Philosophy	—	—	—	—	—	—	—	—	—	—	—	3	—	1	—	—	—	—	3
Political Science	3	3	18	—	—	2	1	1	—	—	—	3	3	5	—	—	—	—	8
Psychology	—	—	—	—	—	—	—	—	—	—	—	1	2	2	—	—	—	—	7
<b>Total</b>	11	6	82	—	—	5	5	2	—	—	—	17	7	17	—	—	—	—	33
<b>Total</b>	48	29	387	4	—	184	126	174	—	17	25	84	29	44	45	11	28	22	273

**Alfred P. Sloan School of Management**

Management	2	1	50	—	—	—	—	—	—	—	13	104	—	—	—	5	9	7	—	21	23	161	
<b>School of Science</b>																							
Biochemical Engineering	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	1	1
Biochemistry	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Biology	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Biophysics	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chemistry	—	2	2	33	—	—	—	—	—	—	—	—	—	—	—	—	7	6	9	—	—	—	9
Earth Sciences	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Food Science and Technology	—	4	3	9	2	—	—	—	—	—	—	—	—	—	—	—	18	17	14	—	—	—	50
Geology and Geophysics	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Life Sciences	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mathematics	—	7	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Meteorology	—	4	2	64	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nutrition and Food Science	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nutritional Biochemistry & Metabolism	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oceanography	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Physics	—	6	—	89	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<b>Total</b>	<b>16</b>	<b>14</b>	<b>227</b>	<b>2</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>38</b>	<b>26</b>	<b>29</b>	<b>—</b>	<b>—</b>	<b>52</b>	<b>47</b>	<b>65</b>	<b>2</b>	<b>—</b>	<b>—</b>	<b>324</b>
Without Course Specification	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<b>Grand Total</b>	<b>66</b>	<b>44</b>	<b>672</b>	<b>6</b>	<b>2</b>	<b>1</b>	<b>17</b>	<b>248</b>	<b>175</b>	<b>329</b>	<b>36</b>	<b>4</b>	<b>8</b>	<b>17</b>	<b>25</b>	<b>84</b>	<b>103</b>	<b>110</b>	<b>137</b>	<b>13</b>	<b>28</b>	<b>23</b>	<b>485</b>

\* Beginning 1967-68, the following are considered fields of thesis research and are listed under departments indicated:

- Ceramics — Metallurgy and Materials Science
- Materials Engineering — Aeronautics and Astronautics or Chemical Engineering or Electrical Engineering or Mechanical Engineering
- Materials Science — Metallurgy and Materials Science
- Ocean Engineering — Naval Architecture and Marine Engineering
- Biochemical Engineering — Nutrition and Food Science
- Food Science and Technology — Nutrition and Food Science
- Nutritional Biochemistry and Metabolism — Nutrition and Food Science
- Oceanography — Geology and Geophysics or Meteorology

**Table IX. Number of Degrees of Bachelor of Science Awarded**

All statistics on degrees are arranged by school as of the current year. During the years 1868-1949 the general divisions were Architecture, Engineering, and Science. In 1950 the School of Humanities and Social Studies was established and in 1951 the School of Industrial Management (after 1963, the Alfred P. Sloan School of Management) was added.

	Total by Decades										Grand Total	Calendar year since 1964 (included in decade total)						
	1868-70	1871-80	1881-90	1891-1900	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60		1961	1964	1965	1966	1967	1968	1969
<b>School of Architecture and Planning<sup>1</sup></b>																		
Architecture	—	12	24	162	188	233	223	23										
Architectural Engineering <sup>2</sup>	—	—	—	—	—	—	108	64										
Art and Design	—	—	—	—	—	—	—	—			10	10	—	—	1	—	—	8
<b>Total</b>	<b>—</b>	<b>12</b>	<b>24</b>	<b>162</b>	<b>188</b>	<b>233</b>	<b>331</b>	<b>87</b>	<b>—</b>	<b>—</b>	<b>10</b>	<b>1,047</b>	<b>—</b>	<b>—</b>	<b>1</b>	<b>—</b>	<b>1</b>	<b>8</b>
<b>School of Engineering</b>																		
Aeronautical Engineering	—	—	—	—	—	—	68	287	526	340	—	1,221	—	—	—	—	—	—
Aeronautics and Astronautics	—	—	—	—	—	—	—	99	114	55	496	551	44	67	57	62	74	62
Building Engineering and Construction	—	—	—	—	—	372	32	434	740	131	726	376	42	45	45	35	21	22
Chemical Engineering	—	—	—	91	123	571	99	90	95	108	1	393	—	—	—	—	—	—
Chemical Engineering Practice	—	—	—	—	—	—	504	284	272	457	236	3,251	14	17	34	33	30	18
Civil Engineering	12	84	86	256	407	504	653	284	272	1,218	1,518	1,728	7,407	221	220	190	193	174
Electrical Engineering (including VI-A)	—	—	—	—	28	84	133	56	—	—	—	301	—	—	—	—	—	—
Electrochemical Engineering <sup>3</sup>	—	—	—	—	—	6	226	222	230	133	—	817	—	—	—	—	—	—
General Engineering	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mechanical Engineering (including II-A)	5	40	147	329	502	623	797	602	1,164	1,049	514	5,772	55	57	45	61	40	35
Metalurgy and Materials Science <sup>4</sup>	—	—	—	—	—	—	—	52	194	311	168	725	24	18	19	16	10	14
Military Engineering	—	—	—	—	—	—	1	4	—	—	—	5	—	—	—	—	—	—
Mining Engineering and Metallurgy	8	44	64	74	250	129	174	137	—	—	—	880	—	—	—	—	—	—
Naval Architecture and Marine Engineering	—	—	—	43	133	69†	100	173	234	139	65	956	6	10	8	11	4	7
Sanitary Engineering	—	—	—	29	54	123	34	20	4	—	—	264	—	—	—	—	—	—
<b>Total</b>	<b>25</b>	<b>168</b>	<b>369</b>	<b>1,157</b>	<b>1,846</b>	<b>2,378</b>	<b>3,888</b>	<b>3,179</b>	<b>4,791</b>	<b>4,967</b>	<b>3,602</b>	<b>26,370</b>	<b>406</b>	<b>434</b>	<b>398</b>	<b>411</b>	<b>330</b>	<b>332</b>
<b>School of Humanities and Social Science</b>																		
Economics <sup>5</sup>	—	—	—	—	—	—	—	—	—	—	96	96	—	—	15	16	31	34
Economics, Politics, and Engineering or Science	—	—	—	—	—	—	—	—	61	—	152	100	313	28	25	—	—	—
Humanities and Engineering or Science <sup>5</sup>	—	—	—	—	—	—	—	—	—	49	318	367	32	32	43	40	36	33
Political Science <sup>6</sup>	—	—	—	—	—	—	—	—	—	—	85	85	—	—	16	22	26	21
<b>Total</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>61</b>	<b>201</b>	<b>599</b>	<b>861</b>	<b>60</b>	<b>57</b>	<b>74</b>	<b>78</b>	<b>93</b>	<b>88</b>



<b>Alfred P. Sloan School of Management<sup>6</sup></b>												
<b>Business and Engineering Administration Management<sup>10</sup></b>												
<b>Total</b>												
	—	—	—	142	872	641	909	732	—	3,296	—	—
	—	—	—	—	—	—	—	172	485	657	46	51
<b>Total</b>				<b>142</b>	<b>872</b>	<b>641</b>	<b>909</b>	<b>904</b>	<b>485</b>	<b>3,953</b>	<b>46</b>	<b>51</b>
<b>School of Science</b>												
Biology or Natural History (including VII-A) <sup>7</sup>	—	3	11	25	27	49	57	116	16	507	—	—
Chemistry	2	27	80	154	151	111	141	166	232	207	281	32
Earth Sciences <sup>8</sup>	—	—	—	—	—	—	—	—	—	100	100	6
Food Technology and Biochemical Engineering	—	—	—	—	—	—	—	—	35	62	11	—
General Science or General Course	2	11	17	49	20	26	17	73	58	62	—	—
Geology and Geophysics <sup>8</sup>	—	—	—	8	6	3	36	22	32	141	—	—
Life Sciences <sup>7</sup>	—	—	—	—	—	—	—	—	—	248	—	—
Mathematics	—	—	—	—	—	—	—	—	—	242	25	21
Meteorology	—	—	—	—	—	—	19	48	72	220	735	1,094
Physics	—	5	6	24	19	21	49	170	306	617	992	2,209
<b>Total</b>	<b>4</b>	<b>46</b>	<b>114</b>	<b>260</b>	<b>223</b>	<b>210</b>	<b>319</b>	<b>608</b>	<b>865</b>	<b>1,463</b>	<b>2,377</b>	<b>6,489</b>
<b>Grand Total</b>	<b>29</b>	<b>226</b>	<b>507</b>	<b>1,579</b>	<b>2,257</b>	<b>2,963</b>	<b>5,410</b>	<b>4,515</b>	<b>6,626</b>	<b>7,535</b>	<b>7,073</b>	<b>38,720</b>
												<b>771</b>
												<b>805</b>
												<b>794</b>
												<b>867</b>
												<b>761</b>
												<b>722</b>

\* Includes only February and June degrees.

† Two received the degree in Naval Architecture, Course XIII-B, in 1916 and three in 1917.

‡ See also Table XI.

<sup>2</sup> Prior to 1923 degrees were awarded in Architecture.<sup>3</sup> Prior to 1909 this Course was designated as Option 3 (Electrochemistry) of Physics.<sup>4</sup> Prior to 1938 these degrees were included in Mining Engineering and Metallurgy; changed to Metallurgy and Materials Science, January, 1968.<sup>5</sup> Prior to 1958 these degrees were included in General Engineering and General Science or General Course.<sup>6</sup> Changed to Alfred P. Sloan School of Management after 1963.<sup>7</sup> Changed to Life Sciences beginning January, 1962.<sup>8</sup> Changed to Earth Sciences beginning February, 1961.<sup>9</sup> Prior to September, 1965, these degrees were included in Economics, Politics and Engineering or Science.<sup>10</sup> Prior to February, 1967, Industrial Management.

Table X. Number of Degrees of Master of Science Awarded

	Total by decades										Calendar year since 1964 (included in decade total)					
	1886-90	1891-1900	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961	Grand Total	1964	1965	1966	1967	1968	1969
<b>School of Architecture and Planning<sup>1</sup></b>																
Architecture		8	45	31	9	10										
Architectural Engineering <sup>2</sup>																
<b>Total</b>		8	45	31	9	10										
<b>School of Engineering</b>																
Aeronautical Engineering				17	59	76	307	312								
Aeronautics and Astronautics							21	63	563							
Building Engineering and Construction							3	66	21	108						
Ceramics						3	275	13	16	35						
Chemical Engineering		3	2	18	69	152	241	467	365	1,351						
Chemical Engineering Practice					245	284	194	256	87	1,113						
Civil Engineering		1	4	27	53	179	546	350	487	1,295						
Electrical Engineering (including VI-A)			7	43	462	474	546	1,164	1,352	4,048						
Electrochemical Engineering				4	16	8				28						
Fuel and Gas Engineering				15	11					26						
Mechanical Engineering		1	8	22	100	176	388	559	623	1,877						
Metalurgy					8	36	92	230	190	556						
Mining Engineering				9	8	16	60	169	263	53						
Naval Architecture and Marine Engineering				2	1	20	60	67	5	520						
Naval Construction				39	43	89	206			28						
Naval Construction and Engineering										478						
Nuclear Engineering <sup>3</sup>						5		67	242	309						
Petroleum Engineering										20						
Railroad Operation										14						
Sanitary Engineering				2	3	10	53	99	16	191						
<b>Total</b>		5	64	197	1,144	1,553	2,386	3,815	4,225	13,389	462	544	546	484	492	293
<b>School of Humanities and Social Science</b>																
Economics <sup>8</sup>										14						
Economics, Politics, and Engineering or Science						12	16	19	10	57 <sup>11</sup>				3	2	4
Linguistics										1						
Political Science <sup>5</sup>										1						
Psychology <sup>4</sup>										12						
										6						
<b>Total</b>						12	16	19	43	90	3	10	6	8	7	7

Alfred P. Sloan School of Management <sup>f</sup>																	
Management <sup>g</sup>																	
						4	60	122	581	1,101	1,868	121	140	129	132	128	117
School of Science																	
Biology						1	10	19	34	16	107	2	3	2	1	1	3
Chemistry						7	22	51	46	83	299	11	14	14	9	12	5
Food Technology and Biochemical Engineering <sup>h</sup>										4	67						
General Science		1						12									
Geology and Geophysics											1						
Mathematics						2	5	17	48	69	177	7	4	12	7	13	7
Meteorology <sup>i</sup>						9	25	45	96	59	236	7	2	5	4	10	8
Nutritional Biochemistry and Metabolism <sup>h</sup>								35	99	118	331	10	16	10	10	6	3
Nutrition and Food Science <sup>h</sup>										53	53				19	19	15
Oceanography										56	56	10	15	20			1
Physics						2	2			26	26	3	3	6	3	5	1
		3	2	2	16	40	50	121	111	345	15	16	14	11	6		13
<b>Total</b>	<b>2</b>	<b>8</b>	<b>12</b>	<b>41</b>	<b>79</b>	<b>185</b>	<b>301</b>	<b>514</b>	<b>556</b>	<b>1,698</b>	<b>65</b>	<b>73</b>	<b>83</b>	<b>64</b>	<b>72</b>	<b>55</b>	
Without Course specification				5	308	263	123	357	240	1,296	31	35	36	19	29	32	
<b>Grand Total</b>	<b>2</b>	<b>21</b>	<b>121</b>	<b>274</b>	<b>1,544</b>	<b>2,083</b>	<b>2,948</b>	<b>5,286</b>	<b>6,165</b>	<b>18,444</b>	<b>682</b>	<b>802</b>	<b>800</b>	<b>707</b>	<b>728</b>	<b>504</b>	

\* Includes only February and June degrees.

<sup>1</sup> See also Table XI.

<sup>2</sup> Prior to 1923 degrees were awarded in Architecture.

<sup>3</sup> Prior to 1959 included in Chemical Engineering.

<sup>4</sup> Prior to September, 1964, included in Economics, Politics and Engineering or Science.

<sup>5</sup> Considered Engineering until 1950.

<sup>6</sup> Changed to Nutrition and Food Science in 1962 and changed to Nutritional Biochemistry and Metabolism June, 1967.

<sup>7</sup> Considered Engineering until 1956.

<sup>8</sup> Prior to September 1965 these degrees were included in Economics, Politics, and Engineering or Science.

<sup>9</sup> Prior to February, 1967, Industrial Management.

<sup>11</sup> Includes 6 degrees in Political Science awarded in 1965.

**Table XI. Number of Degrees of Bachelor and Master in Architecture and Bachelor and Master in City Planning Awarded**

	Total by decades										Grand Total	Calendar year since 1964 (included in decade total)					
	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80	1981-90	1991-00	2001-10	2011-20		2021-30	1964	1965	1966	1967	1968
Bachelor in Architecture	—	146	126	257	193	722	19	19	22	17	24	18	—	—	—	—	—
Bachelor in City Planning**	—	14	13	4	—	31	—	—	—	—	—	—	—	—	—	—	—
Master in Architecture	63	81	78	191	200	613	16	23	24	35	30	4	—	—	—	—	—
Master in City Planning	—	18	82	114	128	342	20	12	15	24	16	8	—	—	—	—	—
<b>Grand Total</b>	<b>63</b>	<b>259</b>	<b>299</b>	<b>566</b>	<b>521</b>	<b>1,708</b>	<b>55</b>	<b>54</b>	<b>61</b>	<b>76</b>	<b>70</b>	<b>30</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>

\* Includes only February and June degrees.

\*\* From 1935 to 1944, Bachelor of Architecture in City Planning.

Table XII. Number of Degrees of Engineer Awarded

	Total by decades					Grand Total	Calendar year since 1964 (included in decade total)				
	1949-60	1961-	1964	1965	1966		1967	1968	1969*		
Engineer in Aeronautics and Astronautics <sup>1</sup>	35	52	7	4	6	87	7	6	3		
Building Engineer	5	2	1	—	—	7	1	—	—		
Chemical Engineer	17	28	1	3	3	45	1	6	1		
Civil Engineer	21	71	5	4	13	92	5	13	11		
Electrical Engineer	132	375	33	37	49	507	33	70	49		
Marine Mechanical Engineer	7	2	—	1	—	9	—	—	—		
Materials Engineer	—	7	—	2	1	7	—	2	—		
Mechanical Engineer	102	146	16	15	24	248	16	13	13		
Metallurgical Engineer	24	17	1	2	—	41	1	2	—		
Meteorologist <sup>2</sup>	2	—	—	—	—	2	—	—	—		
Naval Architect	11	18	1	4	1	29	1	3	1		
Naval Engineer	334	219	26	31	26	553	26	17	27		
Nuclear Engineer	—	29	1	3	5	29	1	10	4		
Ocean Engineer	—	—	—	—	—	—	—	—	—		
Sanitary Engineer	9	3	—	—	—	12	—	—	—		
<b>Grand Total</b>	<b>699</b>	<b>969</b>	<b>92</b>	<b>106</b>	<b>128</b>	<b>1,668</b>	<b>92</b>	<b>142</b>	<b>109</b>		

\* Includes only February and June degrees.

<sup>1</sup> Prior to 1960 Aeronautical Engineer.<sup>2</sup> Degree discontinued after July, 1955.

Table XIII. Number of Degrees of Doctor of Philosophy Awarded

	Total by decades										Calendar year since 1964 (included in decade total)					
	1907-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-	Grand Total	1964	1965	1966	1967	1968	1969*		
<b>School of Architecture and Planning</b>																
City and Regional Planning	—	—	—	—	—	—	18	18	1	4	1	4	1	6		
<b>Total</b>	—	—	—	—	—	—	18	18	1	4	1	4	1	6		
<b>School of Engineering</b>																
Aeronautics and Astronautics**	—	—	—	—	—	6	46	52	4	6	8	5	10	7		
Chemical Engineering	—	—	—	—	—	—	25	25	3	5	8	3	2	3		
Civil Engineering	—	—	—	—	—	1	42	43	2	4	6	6	13	7		
Electrical Engineering	—	—	—	—	1	9	198	208	18	20	33	32	31	27		
Mechanical Engineering	—	—	—	—	—	4	82	86	8	6	13	13	13	14		
Metallurgy and Materials Science <sup>3</sup>	—	—	—	—	—	6	81	87	8	9	10	7	14	22		
Naval Architecture and Marine Engineering	—	—	—	—	—	—	9	9	1	1	1	—	3	1		
Nuclear Engineering	—	—	—	—	—	5	76	81	8	2	12	8	12	8		
Sanitary Engineering	—	—	—	—	—	2	3	5	—	—	—	—	—	—		
<b>Total</b>	—	—	—	—	1	33	562	596	52	53	91	74	98	89		
<b>School of Humanities and Social Science</b>																
Economics <sup>1</sup>	—	—	—	—	19	96	153	268	19	18	18	26	20	10		
Group Psychology	—	—	—	—	8	1	—	9	—	—	—	—	—	—		
Linguistics	—	—	—	—	—	—	23	23	1	12	1	4	4	1		
Philosophy	—	—	—	—	—	—	5	5	—	—	—	—	—	3		

Political Science	—	—	—	—	—	—	—	58	3	8	9	12	12	8
Psychology	—	—	—	—	—	—	3 <sup>†</sup>	16	19	—	4	2	4	4
<b>Total</b>	—	—	—	—	27	100	255	382	23	42	31	46	41	24
<b>Alfred P. Sloan School of Management</b>														
Management <sup>‡</sup>	—	—	—	—	—	—	—	71	71	6	11	15	13	16
<b>School of Science</b>														
Biology	—	1	10	17	21	38	90	177	12	11	5	15	12	15
Chemistry	7	19	59	146	180	342	348	1,101	32	44	48	41	40	31
Geology and Geophysics	1	7	10	22	20	71	71	202	4	8	8	8	7	6
Mathematics	—	—	6	25	35	70	177	313	21	27	27	15	24	11
Meteorology	—	—	—	—	—	14	34	48	3	3	7	2	4	8
Nutrition and Food Science	—	—	—	—	4	28	54	86	4	10	3	9	12	6
Oceanography <sup>‡</sup>	—	—	—	—	—	—	11	11	1	2	5	2	—	—
Physics	—	2	6	48	159	283	331	829	36	34	44	46	38	35
<b>Total</b>	<b>8</b>	<b>29</b>	<b>91</b>	<b>258</b>	<b>419</b>	<b>846</b>	<b>1,116</b>	<b>2,767</b>	<b>113</b>	<b>139</b>	<b>147</b>	<b>138</b>	<b>137</b>	<b>112</b>
<b>Grand Total</b>	<b>8</b>	<b>29</b>	<b>91</b>	<b>258</b>	<b>447</b>	<b>979</b>	<b>2,022</b>	<b>3,834</b>	<b>195</b>	<b>244</b>	<b>281</b>	<b>277</b>	<b>290</b>	<b>247</b>

\* Includes only February and June degrees.

\*\* Prior to 1960 Aeronautical Engineering.

† Previously included in Industrial Economics.

‡ Changed from Industrial Economics to Economics in 1966.

§ Changed from Industrial Management to Management February, 1967.

¶ Includes Ceramics.

‡ Beginning 1967-68 included in Geology and Geophysics or Meteorology.

Table XIV. Number of Degrees of Doctor of Science Awarded

	Total by decades										Calendar year since 1964 (included in decade total)				
	1911-20	1921-30	1931-40	1941-50	1951-60	1961-	Grand Total	1964	1965	1966	1967	1968	1969*		
<b>School of Engineering</b>															
Aeronautics and Astronautics <sup>1</sup>	2	4	5	18	31	67	127	9	4	5	16	9	5		
Chemical Engineering	—	23	78	114	117	135	467	25	12	18	13	7	9		
Civil Engineering	—	2	12	23	46	67	150	7	9	8	4	6	3		
Electrical Engineering	3	12	30	34	141	114	334	16	22	12	5	8	3		
Electrochemical Engineering	—	1	1	—	—	—	2	—	—	—	—	—	—		
Mechanical Engineering	—	4	13	35	125	140	317	17	16	16	23	15	20		
Metallurgy and Materials Science <sup>2</sup>	—	14	32	86	194	186	512	21	29	29	25	11	7		
Mineral Engineering	1	—	4	—	—	—	5	—	—	—	—	—	—		
Naval Architecture and Marine Engineering	—	1	—	—	2	5	8	—	1	3	—	—	—		
Nuclear Engineering	—	—	—	—	9	43	52	8	7	9	7	3	3		
Petroleum Engineering	—	—	1	—	—	—	1	—	—	—	—	—	—		
Sanitary Engineering	—	—	2	3	18	2	25	—	—	—	—	—	—		
<b>Total</b>	<b>6</b>	<b>61</b>	<b>178</b>	<b>313</b>	<b>683</b>	<b>759</b>	<b>2,000</b>	<b>103</b>	<b>100</b>	<b>100</b>	<b>93</b>	<b>59</b>	<b>50</b>		
<b>School of Science</b>															
Chemistry	—	2	5	4	3	—	14	—	—	—	—	—	—		
Geology and Geophysics	1	2	4	5	2	1	15	—	1	—	—	—	—		
Mathematics	—	2	3	—	1	1	7	—	—	—	—	—	—		
Meteorology	—	—	6	25	17	3	51	—	—	—	1	1	—		
Nutrition and Food Science	—	—	—	3	10	14	27	2	2	3	4	2	1		
Oceanography <sup>3</sup>	—	—	—	—	—	1	1	—	—	—	—	—	—		
Physics	—	5	18	14	7	6	50	1	2	2	1	—	—		
<b>Total</b>	<b>1</b>	<b>11</b>	<b>36</b>	<b>51</b>	<b>40</b>	<b>26</b>	<b>165</b>	<b>3</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>3</b>	<b>1</b>		
<b>Grand Total</b>	<b>7</b>	<b>72</b>	<b>214</b>	<b>364</b>	<b>723</b>	<b>785</b>	<b>2,165</b>	<b>106</b>	<b>105</b>	<b>106</b>	<b>99</b>	<b>62</b>	<b>51</b>		

\* Includes only February and June degrees.

<sup>1</sup> Prior to 1960 Aeronautical Engineering.

<sup>2</sup> Including Ceramics.

<sup>3</sup> Beginning 1967-68 included in Geology and Geophysics or Meteorology.



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**Table XV. Summary of Degrees Awarded (1868–1969)**

Bachelor of Science	38,720
Bachelor in Architecture	722
Bachelor in City Planning (discontinued after 1954)*	31
Master of Science	18,444
Master in Architecture	613
Master in City Planning	342
Master in Public Health (discontinued after 1944)*	104
Advanced Engineering	1,668
Doctor of Philosophy	3,834
Doctor of Science	2,165
Doctor of Public Health (discontinued after 1944)*	9
Doctor of Engineering (discontinued after 1918)*	4
<b>Grand Total</b>	<b>66,656</b>

\* See the 1959 Report of the Registrar for details.

WARREN D. WELLS

**MEDICAL DEPARTMENT**

The number of visits to the Medical Department was 2.9 per cent less than last year. This decrease is largely due to a reduction in the number of visits to the Surgical Clinic. Actually, if it had not been for the fact that the Institute was closed entirely, or closed early, on several days in February, the number of visits to the Medical Clinic would probably have been about 3 per cent greater than last year. The impact of the "Hong Kong" influenza on the Medical Department was small, as the peak of the epidemic among our students presumably occurred during their Christmas vacation.

Last year's report mentioned that the Commonwealth of Massachusetts Bureau of Hospital Facilities had requested that we apply for accreditation by the Joint Commission on Accreditation of Hospitals, in order to maintain our status as an approved vendor for Medicare and Medicaid. The first step in this procedure is to be registered by the American Hospital Association. Unfortunately, no progress can be reported, as the American Hospital Association has not yet made the site visit necessary for registration, though receipt of our application was acknowledged more than a year ago. Fortunately, the Bureau of Hospital Facilities is aware of the slowness of the registration process and is willing to continue our Medicaid and Medicare approval pending action by the American Hospital Association and the Joint Commission.

Our space problem will continue to be acute until the Sancta Maria building is ready for occupancy. We have been assigned the first three floors of this building and hope to be able to move our inpatient facility there next spring. The space vacated in Building 11 will be converted

into doctors' offices. The possibility of expanding our present facilities by building an additional floor and taking over space in the main buildings was carefully studied during the year. This did not prove to be feasible, as it would have been very expensive and still would have offered only a temporary solution to the Medical Department's space needs. We are unhappy that we have to separate our ambulatory and inpatient facilities, as this is bound to be relatively inefficient and will certainly increase our operating costs. We feel strongly that this move must be regarded as a temporary expedient, and that a new Medical Department building, which will house not only our ambulatory and inpatient facilities, but also the Clinical Research Center, should be built as soon as possible.

In the past, we have relied heavily on part-time physicians, depending particularly on young men who were building a private practice. As our part-time associates leave us because of the demands of their practice, we are finding it increasingly difficult to replace them, as very few physicians are going into private practice in this area. It is apparent that we must expand our full-time staff to meet our needs, though we will continue to rely on part-time physicians for such specialties as dermatology, where the load is not great enough to justify full-time personnel.

This year, Dr. Carola B. Eisenberg and Dr. Peter B. Jenney, psychiatrists, and Dr. John Homans, an internist, joined our full-time staff. Dr. James A. Haycox, a psychiatrist, resigned to accept an important administrative position in Arizona. Miss Mary L. Diehl, R.N., M.S., resigned as Director of Nurses, and has been replaced by Mrs. Dorothy B. Brooks, R.N., B.S.

Other appointments during the year included: Roland E. Houle, M.D., Associate Ophthalmologist; Raymond Russo, D.V.M., Veterinarian; Charlotte G. Schwartz, M.A., Research Sociologist; Samuel Shapiro, M.D., Assistant Physician.

Resignations from the staff were submitted by: Herbert Benson, M.D., Assistant Physician; F. Gregory Curtin Jr., M.D., Assistant Surgeon; Thomas Harcus, M.D., Associate Physician; Hugh Miller, M.D., Assistant Physician; Lawrence M. Miller, M.D., Assistant Physician; Edward Schulman, M.D., Physician; Samuel Shapiro, M.D., Assistant Physician; Leo L. Stolbach, M.D., Assistant Physician.

#### CLINICS

As has been mentioned, there was a slight decrease in total number of visits to the Medical Department this year. For the period June 1, 1968-May 31, 1969, the total number of visits to the outpatient clinics was 55,207, while the number for the same period in 1967-1968 was 56,865. It

MEDICAL DEPARTMENT

is of interest, however, that the number of visits to our emergency clinic, which offers care nights, weekends, and holidays, increased by 16 per cent, rising from 3,670 visits in 1967-1968 to 4,263 visits in 1968-1969. The number of clinic visits and the distribution among the various categories of the M.I.T. community are shown in Table I. To some extent the number of patients seen by the Medical Clinics is determined by the physician appointment time available, and at present, this in turn is limited by available space. Therefore, we are concerned that the striking rise (16 per cent) in visits to the Emergency Clinic may in part reflect difficulty in obtaining appointments during regular clinic hours.

**Table I**

Clinic Visits	June 1, 1967- May 31, 1968	June 1, 1968- May 31, 1969
Medical	21,504	21,390
Surgical	11,467	10,397
Other	23,894	23,420
<b>TOTAL</b>	<b>56,865</b>	<b>55,207</b>
Faculty	3,377	3,264
Staff	6,220	6,129
Students	29,246	28,590
Student wives	4,874	4,546
Employees	12,186	11,728
Other	962	950
<b>TOTAL</b>	<b>56,865</b>	<b>55,207</b>

The Prenatal and Obstetrical Program for student wives at the Boston Lying-In Hospital has been discontinued, as the cost of the Program has risen to the point where it offered no economic advantage for our student families over services of equivalent high quality offered by other hospitals.

We are anxious to establish a pediatric program for our students' children, and still hope that this can be arranged with the Pediatric Service of the Cambridge Hospital when their new facilities are completed some time next year.

**SURGICAL SERVICE**

At the end of the current reporting period, the staff of the Surgical Service numbered 28. Of these, four were dentists, two otolaryngologists, two gynecologists, four orthopedic surgeons and 16 general surgeons. In reviewing the activities of the 28 surgeons, they were responsible for 147 surgical admissions, for the treatment of 2,147 surgical emergencies and for seeing a total of 18,162 patients in clinic visits. Compared to the previous year, this represents a 9 per cent increase in surgical admissions, a

15 per cent increase in emergency visits to the Infirmary and a 3.6 per cent decrease in Surgical Clinic visits.

In reviewing athletic injuries, it is noted that a total of 375 were treated in the Infirmary during this period. Of these, 73 were incurred in football, 44 in basketball, 31 in hockey, 25 in soccer, 19 in skiing, 18 in rugby and 16 each in wrestling and softball. There were 19 injuries in judo and karate, and even four from playing with the frisbee. In comparison with the previous year, this represents a 54 per cent increase in total injuries and a significant increase in the injuries in football, basketball, softball, wrestling, and skiing. There has been increased participation in sports, but probably not enough to account for the 54 per cent increase in injuries.

The most common injuries, both athletic and nonathletic, were sprains, strains, contusions, abrasions, and lacerations. The overwhelming majority were treated in the Infirmary, with only 135 patients out of a total of 4,267 being referred to another hospital.

There were a total of 403 operations performed during the year. This was 47 less than the previous year. Among these, there were no major operative procedures requiring a spinal anesthesia or general anesthesia. There were 152 lacerations sutured. A total of 9 malignant neoplasms were removed, 8 being basal cell carcinomas and one a malignant melanoma. The lesions most commonly removed were nevi and the second most common were cysts.

#### DENTAL SERVICE

The number of visits was 3,894, a slight increase over the previous year, and representing about the capacity of the service at present. The Dental Service is now limited to dental hygiene and diagnosis, with therapy referred to private dentists in the community. In the past, this arrangement has been satisfactory, but now it is difficult to find dentists willing to accept student patients, as they are so busy with their regular practice. There is every reason to assume that the shortage of dental services is going to get worse, so we are planning to engage a full-time dentist to cope with at least the most urgent dental problems among our students. Space will become available for this expansion of dental service when the Sancta Maria building is ready for occupancy.

#### HEALTH SURVEYS

Voluntary medical examinations offered to the faculty and senior members of the D.S.R. staff continue to be popular, and 829 examinations were performed during the year. Twenty-five of those examined were emeritus members of M.I.T., age 70 or older.

MEDICAL DEPARTMENT

STAFF AND EMPLOYEE HEALTH PROGRAM

Last year's modest reduction of activity in this area has been matched by a similar reduction during 1968-1969. This is accounted for by changes in two categories, hazardous occupation examinations and those examinations requested on the patient's own initiative.

	1968-1969	1967-1968
Pre-employment	1,312	1,364
Women under 30	753	689
Retirement	86	92
Hazardous Occupation	39	102
Employee Health Survey	194	194
Baseline	97	108
Miscellaneous	450	644
<b>Total</b>	<b>2,931</b>	<b>3,193</b>

PRE-EMPLOYMENT

The total number examined for employment was virtually unchanged (2,065 vs. 2,053). A slightly larger proportion of applicants for employment were women under 30 years of age. These women are not seen by a physician, but have chest x-rays and certain laboratory tests as screening procedures.

There were 19 applicants who were found to have conditions which medically disqualified them for the positions they sought. Lung disease was by far the commonest cause of rejection, seven such instances being found (one with active tuberculosis, two with emphysema and pulmonary insufficiency, and four with abnormal chest x-rays of unknown cause). Other diseases that disqualified applicants were heart disease, alcoholism, abdominal tumor, uncontrolled diabetes, severe varicose veins with ulceration, neurological disease, and, as usual, deafness in a lady who sought employment as a telephone operator. The rejection rate this year was slightly higher (0.9 per cent) than the average rate over the past several years (0.7 per cent).

Thirty-five applicants for employment were found to have health problems which, although important, did not interfere with their capability to perform the jobs they sought. In this group the most common health problems discovered were: hypertension (7), abnormal chest x-ray (6), heart disease (5 — one mitral valve replacement, one aortic reconstruction), seizure disorder (3). Also encountered were anemia, cancer (post-operative), cervical disc disease, severe eczema, emotional disturbance, histoplasmosis of the retina, renal disease, thyrotoxicosis, ulcerative colitis and severe varicose veins. Twelve of the 35 new employees with nondisqualifying health problems are being followed in the Medical Department.

RETIREMENT

No retirements for medical reasons were recommended this year.

HAZARDOUS OCCUPATION

The much smaller number of men in this category this year is accounted for by two factors: only those over 45 years of age were due to be examined, and a delay was encountered in notification of a large group of employees at Lincoln Laboratory, who were, therefore, not examined during the period covered by this report. Their number will increase next year's total. Two employees were found to have health problems of sufficient severity as to make it advisable that they change their jobs.

EMPLOYEE HEALTH SURVEY

The number of invitations and acceptances this year were remarkably similar to those of a year ago. This year, 508 employees who reached age 45, 50, 55, 60, and 63 were offered health survey examinations. The acceptance rate of 38.6 per cent was precisely the same as last year.

BASELINE

After one year of employment, women under 30 who did not have a complete health survey when hired are invited to have such an examination in order to establish a baseline medical record. This year, 331 invitations were sent and 97 accepted the invitation. This acceptance rate is about the same as in previous years.

MISCELLANEOUS

This category represents the major decrease in activity over last year (450 compared with 644). These examinations are requested for a variety of reasons, but usually are needed for employment or graduate school applications. We suspect that the draft situation accounts for most of the reduction in the number of these examinations.

DEATHS

There were 29 deaths in the M.I.T. community this year. Heart disease (11), cancer (9), and accident (4) were again the commonest causes. Other causes were brain disease, nature not specified (2), cerebrovascular accident, hepatic cirrhosis, and emphysema.

PSYCHIATRIC SERVICE

Dr. Benson R. Snyder has resigned his position as Psychiatrist-in-Chief to become Dean for Institute Relations beginning July 1, 1969. Dr. Snyder has developed a distinguished psychiatric service which is influencing psychiatric care in universities throughout the world. His final report follows:

My final annual report is a time for looking back and looking ahead. I will speak to where I think we have been and where the Service might go in the future.

Over the last 9 years the number of undergraduate students and the total number of visits have more than doubled (239 undergraduates in 1959-1960 to 517 this past academic year; the number of graduate students going from 93 to 180; the total visits from 1,400 to 3,135). The most dramatic increase, however, has occurred in the use of the Service by other groups, including faculty, staff, and employees; from 11 nine years ago to 324 this year, a thirty-fold increase. At the beginning of this period, the staff consisted of one full-time and 5 part-time psychiatrists. There are now 5 full-time and 5 part-time psychiatrists, a part-time psychologist, and the cooperation of the Medical Department's social worker.

These numbers, however, do not tell very much about the qualitative shifts that have occurred during this period. The majority of individuals who have come for consultation have not experienced disabling failure in their academic or social life; nor have they necessarily seen themselves as patients. Rather, they sensed some discrepancy between the demands of the Institute environment and their own expectations for themselves. They were seldom pleased with themselves and spoke of their personal dissatisfactions usually with considerable sensitivity. I have come to view such individuals' questioning as often growing self-awareness and not necessarily illness. They were asking questions about their interaction with their environment.

The psychiatrist working in a university setting has to make a decision here. He can comfort the individual, reassure him that all is well, and treat his anxiety as if it were a fever, giving aspirin. An alternate approach, and the one that characterizes this Service, is to understand with the individual the nature of the current situation which led to his request for reassurance or for help. It became as important to understand the source of pain as it was to make the patient comfortable (though the latter goal was not ignored). This approach has led to some shift over the past decade in the role of the psychiatrist and in the function of the Psychiatric Service. This shift in the physician's role and the Service's function results from seeing a normal psychological reaction to stress in essentially healthy, late adolescents. In the process we have learned much about the varieties of individual response to our environment and about the nature of that environment.

When a psychiatrist works within a particular institutional setting, there is a constant risk that he may consider a therapeutic success to have occurred when the individual who consulted him can work more rapidly, take exams without anxiety, express himself with facility, and appear more adjusted and perhaps even more polite. All this can occur even though the student has made no significant commitment to his educational experience. This and similar outcomes led us into a series of inquiries on this institution's effect on the students' adaptation to its educational demands. In the clinical work and in the research, we have begun to see the specific ways this institution influences the patterns of its students' adaptation, the psychological defenses which students use to deal with the pressures of this environment, or the anxieties that develop as they live within this particular setting.

Approximately one-third of each class over their four years here has consulted us at points which they defined as stressful. The insights that come from this experience have been taken into many, many meetings with faculty, with students themselves, and with members of the administration. In most of these meetings it has been possible for a perspective and a series of questions to be posed by members of this staff that otherwise would not have been raised or presented. The Psychiatric Service has not put all its energy or resources into providing intensive, long-term psychotherapy for a few (a not unusual pattern) but has developed a series of dialogues with the community about its possible short- and long-term impact on the lives of its members.

Our central task has been (1) to be responsive to the felt needs of our constituency, to permit the individual to define what he considers his relevant problem,

and to start at this point in clarifying what lies behind it; (2) to take enough time to clarify the present dilemma of those consulting the Service in the light of the past and their present pressures, and consider the range of strategies available to the student or faculty working out a longer-term solution; (3) to aggregate our individual experience and to consider the epidemiology of distress or stress, for example; and (4) to identify and understand the range of supports necessary for faculty, for students, for staff, so that they will be more able to live productively in this community.

This combination of clinical approach, involvement with our educational community, and the research which developed, received generous National Institute of Mental Health support a year ago. This grant has made possible training young professionals in a program for academic psychiatry, where clinical experience is informed by the more formal and systematic study of the environment in which the individuals live.

None of these developments would have been possible without the understanding, the moral and financial support of the Medical Director, the Vice President for Academic Affairs, and the support of two Provosts and two Presidents of M.I.T. The staff has been central to the growth and development of the Service. They have worked long and hard and have tolerated much ambiguity, as we found our collective way into our own approach to community psychiatry. These past years have been an extraordinarily rich and rewarding experience.

There are problems in the present; the most crucial is in part a function of our success. The Service has so grown in size that the small, intimate group can no longer easily and casually meet in an office to view the preceding week's crises or events. Decision making can no longer be assumed by some "sense of the meeting" but increasingly, will have to be delegated, decentralized. The roles of the administrative assistant, the secretaries, as well as the full-time and part-time professional staff, are all in the process of redefinition. Restrictions in communication almost invariably attend an increase in the size of a group. Maintaining the openness, the trust, the free flow in information within this larger group will call for imaginative innovation on the part of the staff. Let me give one other example of a problem born of our success. The time between an individual request for consultation and that individual's being seen has at times this year stretched to two weeks, occasionally more. Several plans are under consideration, whereby everyone can be seen within a day.

The relationship of the Psychiatric Service to the Infirmary has been crucial in our developing an effective emergency service. The support of the Campus Patrol has also been central in our having been able to respond. We have learned much about the crisis situation here over the years. We have been able to return more individuals back into the community with less delay than the receiving wards of nearby hospitals. As pressures mount within the community, it is likely that this emergency function of the Service will assume even greater significance than it has in the past.

In the future the Psychiatric Service will need to work closely with the Medical Department, particularly as joint teaching programs in the Bio-Engineering, Bio-Medical program are developed. The relationship of our research to the ongoing work of the Medical Department also needs to be strengthened. The communication between the clinical work of the Psychiatric Service and the Medical Department needs further improvement.

I am indeed grateful to M.I.T., to the Medical Department, and to countless others for the major part they played in educating their Psychiatrist-in-Chief.

#### SOCIAL WORK SERVICE

During the period of June 1, 1968, to May 31, 1969, there were 617 visits to the Social Work Service, with a total case load of 333 clients. There



MEDICAL DEPARTMENT

**Table II Psychiatric Service 1968-1969**

Total individuals seen:	1,076	
Total number of visits:	3,135	
<b>Analysis of caseload:</b>	<b>Number of Patients Seen</b>	<b>Size of Class</b>
Total undergraduates	517	3,960
Freshman	90	973
Sophomore	114	973
Junior	126	966
Senior	187	1,048
Graduates	180	3,809
Uncertain status	31	
Faculty, staff, employees	208	
Other	140	
	<b>Number of New Patients</b>	<b>Total Number of Patients</b>
Undergraduates	304	517
Graduates	122	180
Faculty, staff, employees	155	208
Other	113	140
Total number of patients hospitalized:	14	
Total number of patients referred on:	119	
To clinic	44	
To private psychiatrist	75	

was a significant increase this year in the number of student visits to the Service, particularly of undergraduates and foreign students. More student wives were seen this year than in the previous year.

In addition to clients seen at the request of the Medical and Psychiatric staff, the Service continued in a collaborative effort with other departments within the Institute, the Housing Office, the Foreign Student Office, the Personnel Department, and so forth. In addition, a substantial group who used the Service came self-referred.

The problems presented continue to be infinitely varied. Among these, marital and family problems; problems created by and associated with mental or physical illness as it affects family, studies or job; problems generated by the educational experience, per se, or related to the particular stress of graduate study; and problems encountered in the process of resettlement for, particularly, the foreign student family, tend to be discussed with the greatest frequency.

This year, there were beginning attempts to identify the special needs of blind students on campus, and to organize a group of concerned volun-

teers within the M.I.T. community to provide concrete assistance to this group.

During the past few months, social work coverage was extended to the Clinical Research Center. More time was made available for consultation with teachers and families of the Technology Nursery School. Home and hospital visiting was done on a selective basis, when appropriate. The social worker continued to represent M.I.T. as a member of the Cambridge Community Services.

**INFIRMARY**

Total admissions to the Homberg Infirmary in the past ten years have ranged from 590 in 1959-1960 to 719 in 1965-1966, the average being 654 per year. In 1968-1969, there were 615 admissions (Table III).

**Table III**

Infirmary admissions	1967-1968	1968-1969
Medical	494	426
Surgical	104	117
Orthopedic	29	30
Psychiatric	29	42
<b>TOTAL</b>	<b>656</b>	<b>615</b>
<b>Emergency clinic</b>		
Medical	1,798	2,061
Surgical	1,637	1,972
Orthopedic	193	175
Psychiatric	42	55
<b>TOTAL</b>	<b>3,670</b>	<b>4,263</b>

Average duration of stay in recent years has been remarkably constant, ranging from 3.22 days to 3.86 days, the past year being 3.39 days per patient. Despite the stability of total admissions over the years, the patient load has fluctuated from a predictable low in the summer to a peak admission rate of 82 patients in the month of December 1968. Christmas vacation undoubtedly prevented a serious overloading of Infirmary facilities at that time.

Emergency clinic usage has continued the previously noted rise. In 1959-1960, there were 1,792 visits, and the number has climbed steadily (with the sole exception of 1966-1967) to the 1968-1969 total of 4,267 visits. The distribution of visits is given in Table III. Available space has been a major problem in the operation of emergency facilities. In

#### MEDICAL DEPARTMENT

May of 1969, 474 visits were recorded, most of these on Saturday and Sunday. The presently available examining and treatment areas are totally inadequate and interfere greatly with the operation of the Infirmary itself. The 1970 move of the Infirmary and emergency facilities to the old Sancta Maria Hospital building will relieve physical congestion. If the present ten year trend of increased use continues (nearly 2.5 times as many patients as ten years ago), even these quarters and plans will be inadequate within a few years.

#### ELECTROCARDIOGRAPHIC LABORATORY

A total of 1,488 electrocardiograms were taken during the year, representing an increase of 3.5 per cent over the previous year. A unit including a cardiac monitor, defibrillator and pacemaker was purchased, but fortunately, we have not needed to use it.

#### X-RAY DEPARTMENT

The activity of the X-ray Department increased by 3.5 per cent, with a total of 11,180 x-rays taken during the year. While there was a slight decrease in the number of chest x-rays, there was a 19 per cent increase in other x-rays. This difference is important in evaluating the activity of the Medical Department, as many chest x-rays are taken because of the routine screening for tuberculosis required by law, but almost all other x-rays are ordered to investigate active or suspected medical problems.

#### CLINICAL LABORATORY

The clinical laboratory continues to be operated under contract with the Commonwealth Clinical Laboratory. Three technicians employed by them are assigned to our laboratory. A total of 26,397 laboratory procedures were performed representing an increase of 8 per cent over the previous year.

#### SANITATION

Routine bacteriological monitoring of the M.I.T. food services and swimming pool is performed by the Massachusetts Dairy Laboratories. Mr. Fred E. Smith, our Consultant Sanitary Engineer, reviews the bacteriology reports and inspects the facilities at least once a month. One of the chief problems in the past has been the maintenance of proper sanitation of cream, as dispensers can be contaminated so easily. The substitution of single serving cream packages has eliminated this difficulty. The swimming pool is being very heavily used, but meticulous control of chlorination by the swimming pool personnel has kept the water in excellent sanitary condition.

**STUDENT HEALTH INSURANCE**

This year the Student Health Insurance became mandatory for all students who did not have health insurance coverage, which included reasonable benefits for both hospitalization and ambulatory care with a deductible feature no greater than \$100.00. A total of 6,390 students were covered by the Student Health Program during the first semester and 6,026 during the second semester. There was surprisingly little overt unfavorable student reaction to the introduction of compulsory insurance, though what there was tended to be rather loud. The chief complaint was that the Student Health Program was an extra fee, rather than incorporated into tuition, and as a consequence, some graduate students had it paid for by their fellowship arrangements, whereas others had to pay it themselves. A total of 705 student wives purchased the insurance in both semesters. Student wives not carrying the Student Health Insurance used the Medical Department, but were billed on a fee for service basis.

**OCCUPATIONAL MEDICAL SERVICE**

The activity of this Service continues to increase because of the expansion of Institute activities which require radiation and industrial hygiene protection. As an example the 400 MeV Linear Accelerator being built by the Laboratory for Nuclear Science requires very sophisticated radiation protection assistance.

During the year, Edwin D. Flack, M.S. and Richard L. Lehman, Ph.D. joined the staff as Radiation Protection Biochemist and Associate Radiation Protection Officer respectively. Raymond M. Diffley Jr., B.S., Radiation Protection Physicist, resigned.

Dr. Harriet L. Hardy, Assistant Medical Director in charge of the Occupational Medical Service, and her associates take advantage of every opportunity to teach, as they strongly feel that M.I.T. students should be familiar with the potential hazards created by technology. During the year, lectures have been given in several departments, but the Service feels that more teaching should be done. Seven seminars on subjects related to occupational medicine were arranged by Dr. Hardy and were well received. She is planning to continue this program next year.

The following reports on the Industrial Hygiene Office and the Radiation Protection Office were prepared by Mr. Richard I. Chamberlin and Mr. Samuel Levin respectively.

**INDUSTRIAL HYGIENE OFFICE**

The normal service operations conducted have been essentially the same as those reported in previous years; namely, advice on toxicity of ma-

terials, ventilation surveys, and advice on proper control ventilation, the hood survey and labelling program, evaluation of potential exposures, recommendations for control of contaminants, on-site supervision of filter changing operations, and the Institute respirator program. These general services continue to be well received and the demand is still increasing.

There have been major changes in the scope of two of these activities during the past year. The hood survey and labelling program has had to be curtailed due to lack of technician help, but the Institute respiratory protection program has been expanded. The self-contained, positive pressure, respiratory equipment that is now included in our program has been of great value on many occasions. Our portable exhaust systems also have been used extensively.

There continues to be good liaison between our group and the M.I.T. Physical Plant Department relative to new or revisions of existing laboratory ventilation. Considerable time has been spent on the surveillance of hood installations in the new chemistry building. This project is of special interest, since the Industrial Hygiene Office group has been named as the responsible agency for the overall balancing of these hood systems. Accepting this responsibility, which was introduced into the main building specifications at our request, is the first time this approach has been taken. It is our opinion that this will both assure M.I.T. of an acceptable installation, and assist the Industrial Hygiene Office by integration of these hoods into our overall hood survey and labelling program.

The acquisition of approximately 800 square feet of floor space in Building E-15A has been a great boon to the engineering activities of the Industrial Hygiene Office group. This space has enabled us to continue our development work relative to good laboratory hood design and has also made it possible to undertake such projects as fan performance testing. It is also planned that the airflow calibration unit, now located in the sub-basement of Building 56, will eventually be set up in this area.

The Industrial Hygiene Laboratory continues to be engaged in both direct service and research activities. Analyses for such contaminants as lead, mercury, selenium, and beryllium continue to be performed on both air and biological samples as an evaluation of routine exposures in various laboratories. These exposures often provide our laboratory with the opportunity to perform additional work of a research nature. In conjunction with the lead studies, considerable work was also performed relative to the use of the atomic absorption technique for analysis of lead in urine samples. As a result of this work, a paper was presented at the American Industrial Hygiene Association Conference on the use of the Jarrell-Ash Atomic Absorption Apparatus for determination of low

level lead in urine. Of special interest was the further refinement of analytical procedures for analysis of beryllium in tissue.

#### RADIATION PROTECTION OFFICE

The number of laboratories involved in radioisotope use was 295 as of May 30, 1969, an increase of 25 over the previous report period. The procedure for review of radioisotope-use authorizations has been modified. A new procedure is the practice of re-review with the applicant of the initial Radiation Protection Office review on a routine two year basis. Of the 875 persons currently registered as radiation workers, 550 are working with radiation sources which warrant issuance of a film badge for personnel monitoring of external radiation exposure. A new film badge service provides two important improvements in our program; namely lifetime totaling of occupational radiation exposure, and also the change to a new type of film badge for personnel monitoring of beta, gamma, and x-ray exposure.

The Radiation Protection Office shadow-shield whole body counter unit continues to be used extensively for monitoring personnel. The thyroid probe, added last year, has proved to be very effective for the detection of radioiodine in the thyroids of workers using such material. A review of the overall wholebody counting program indicated that approximately 7 per cent of the people counted are found to have detectable body burdens of materials other than the normal background radio-nuclides.

The Central Radioisotope Laboratory and Storage Facility continues to be used extensively by various M.I.T. departments and was used during the year by visiting professors from the University of Massachusetts, Boston University, University of Hawaii, and the Woods Hole Oceanographic Institution.

The radioactive-waste disposal program has increased so that it is necessary to utilize one technician fulltime to maintain the program.

Starting on March 21, for a three-week period (including weekends) extensive radiation protection coverage was provided to Reactor personnel during operations associated with the shipment from the Reactor of 56 spent-fuel elements. During the year, installation was completed of a network for collecting samples in the Reactor's Controlroom from remote sampling stations located at the Reactor top, main-floor, and the primary and secondary chemistry rooms.

The Laboratory for Nuclear Science's 400 MeV Linear Accelerator is scheduled for initial operation (at 100 MeV) in the spring of 1970. During the year, evaluations and plans have been made for anticipated radiation protection problems associated with (1) direct-beam scattered

## PLACEMENT BUREAU

radiation, (2) induced activity in shielding walls, machine components and cooling water, (3) the production of radioactive and noxious gases and (4) x-radiation from the LINAC modulator components.

Lincoln Laboratory visits by Radiation Protection Office personnel have continued on a periodic and special-need basis. Lasers and x-ray diffraction units were the principal items involving Radiation Protection Office services. At the request of Lincoln Laboratory, Dr. Richard L. Lehman of the Radiation Protection Office travelled to Kwajalein to evaluate potential x-radiation hazards associated with the operation of some klystron units.

ALBERT O. SEELER, M.D.

## PLACEMENT BUREAU

### STUDENT PLACEMENT

A total of 1,342 students took 6,075 interviews with 303 companies, 40 government agencies, and 12 graduate schools, who visited the Placement Bureau during the past year. This was a 20 per cent decrease over last year. Many companies were forced to cancel either because of cut-backs from within or because of a lack of interest shown by our students. Some cancelled because of the series of severe snow storms last winter.

Evidence of the impact of the Selective Service changes made in 1967 was once again apparent. More of our students at the Bachelor's level continued to choose an industrial career rather than attend graduate school, as had been the case in 1966 when 79 per cent went on for further study. The same is also true for the Master's recipients, with only 26 per cent continuing for an advanced degree. (See Tables I-V)

A sharp increase was noted in the salary offers made; because of the inflationary trend they were approximately 9 per cent higher than last year. The median offer to S.B. graduates was \$835; Master's recipients, \$1,000; and doctoral candidates, \$1,335. (See Table VII)

During the academic year 1969-70, the scope of the Placement Bureau will continue to widen, as more emphasis is placed on career counseling. A series of small seminars will be sponsored by this office under the auspices of its new Director, Mr. Robert K. Weatherall.

EDWARD J. CAREY JR.

### ALUMNI PLACEMENT

The number of men registering for new positions increased by 4 per cent over last year. The significant difference between the groups is that this year a much larger number of them needed new positions because they expected to become unemployed. Another difference is that they

were a little older than is usual, approximately 38, on the average, when traditionally they are 34-35 years old.

This year, the number of men with Ph.D.'s constituted 22 per cent of the list. Last year it was 21 per cent. The number of placements made was up 11 per cent, partly because of the excellent quality of the available men, and partly because the requests for people, reduced by 22 per cent, relieved us of a normally impossible load of paper work. It is good to be able to report that 19 per cent of our placements were men with the Ph.D. degree.

It is too early to predict what the new fiscal year will bring, but if it continues as it is starting out, any man who already has a good job is not likely to get restless.

EVELYN B. YATES

**Table I Class of September, 1968, February, 1969, June, 1969**

	Placement by Field			
	S.B.	S.M.	Prof.	Ph.D./Sc.D.
<b>Academic Research</b>				
M.I.T.	3%	4%	4%	11%
Elsewhere	—	—	—	7%
<b>Teaching</b>				
M.I.T.	—	—	—	6%
Elsewhere	2%	2%	—	21%
<b>Further Study</b>				
M.I.T.	14%	21%	37%	1%
Elsewhere	33%	5%	2%	2%
<b>Industry</b>	20%	35%	15%	33%
Government	3%	6%	4%	5%
Armed Services	2%	6%	25%	1%
<b>Foreign Students</b>				
Return Home	2%	9%	6%	7%
Miscellaneous	—	1%	—	1%
Undecided	4%	2%	—	1%
Unknown	17%	9%	7%	4%



PLACEMENT BUREAU

Table II S.B. Degree  
Class of September, 1968, February, 1969, June, 1969  
Placement by Field

Course	Acad.		Res.		Teaching		Further Study		Industry		U.S. Gov't		Armed Service		For'gn Stud.		Misc.	Un-decided	Un-known	Total
	MIT	Other	MIT	Other	MIT	Other	MIT	Other	U.S.	Other	U.S.	Other	Armed	Other	For'gn	Home				
1	—	—	—	—	4	4	4	4	4	4	2	—	—	—	1	1	—	—	—	16
2	—	—	—	—	8	3	—	8	8	8	—	1	1	—	—	1	—	—	6	27
3	—	—	—	—	2	5	—	4	4	4	—	1	1	—	—	—	—	—	—	13
4	—	—	—	—	1	—	—	5	5	2	2	1	1	—	1	1	—	—	3	14
5	—	—	—	—	4	28	—	2	2	—	—	—	—	—	—	—	1	—	—	35
6	7	1	—	—	22	37	3	44	44	8	8	2	2	—	4	3	—	—	36	167
7	1	—	—	—	4	25	—	16	16	—	—	—	—	—	2	1	—	—	5	38
8	4	—	—	—	9	48	1	5	5	1	1	1	1	—	4	1	—	—	3	87
10	—	—	—	—	3	5	—	6	1	1	1	1	1	—	—	—	—	—	3	18
12	1	—	—	—	—	6	—	1	1	—	—	—	—	—	1	1	—	—	1	13
13	—	—	—	—	1	1	—	1	1	1	1	1	1	—	—	—	—	—	2	8
14	—	—	—	—	2	10	—	4	4	2	2	—	—	—	1	1	—	—	6	28
15	2	—	—	—	12	5	—	11	11	1	1	3	1	—	3	1	—	—	2	41
16	6	—	—	—	17	7	—	21	21	—	—	1	1	—	1	—	—	—	9	62
17	—	—	—	—	2	6	—	1	1	—	—	—	—	—	1	1	—	—	7	20
18	—	—	—	—	5	23	—	9	9	2	2	—	—	—	2	1	—	—	19	64
21	1	—	—	—	—	17	—	3	3	2	2	—	—	—	—	—	2	—	8	37
<b>Total</b>	<b>22</b>	<b>1</b>	<b>—</b>	<b>—</b>	<b>96</b>	<b>230</b>	<b>15</b>	<b>138</b>	<b>138</b>	<b>21</b>	<b>21</b>	<b>12</b>	<b>14</b>	<b>5</b>	<b>24</b>	<b>110</b>	<b>5</b>	<b>24</b>	<b>110</b>	<b>688</b>

**Table III S.M. Degree  
Class of September, 1968, February, 1969, June, 1969  
Placement by Field**

Course	Acad.		R.es.		Teaching		Further Study		Industry	U.S. Gov't	Armed Service	For'gn Rtn Home	Stud.	Misc.	Un- decided	Un- Known	Total
	MIT	Other	MIT	Other	MIT	Other	For'n Stud.	Home									
1	1	—	—	—	—	1	5	4	11	5	3	4	—	—	1	5	40
2	7	—	—	—	—	4	20	1	50	1	5	8	—	—	1	9	105
3	—	—	—	—	—	—	3	1	3	1	—	4	—	—	—	1	13
4	2	—	—	—	—	1	1	—	13	1	—	3	—	—	4	16	42
5	—	—	—	—	—	—	1	3	1	—	—	2	—	—	—	2	9
6	14	1	—	—	—	2	48	11	45	4	5	7	—	—	—	2	140
7	2	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	3
8	—	—	—	—	—	—	7	2	3	1	2	—	—	—	—	1	17
10	—	—	—	—	—	—	7	—	18	—	1	3	—	—	—	2	31
11	—	—	—	—	—	—	1	—	—	1	1	—	—	—	2	5	11
12	—	—	—	—	—	—	3	3	1	—	4	2	—	—	—	4	17
13	—	—	—	—	—	—	6	—	6	4	3	3	—	—	—	2	25
14	1	—	—	—	—	—	2	1	—	—	1	—	—	—	—	3	8
15	—	—	—	—	—	—	3	3	74	16	3	22	—	—	2	5	131
16	4	—	—	—	—	—	7	4	19	8	8	2	—	—	1	1	55
17	—	—	—	—	—	—	—	2	2	—	—	—	—	—	1	—	5
18	—	—	—	—	—	—	10	—	1	—	—	—	—	—	—	—	12
19	1	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	7
20	—	—	—	—	—	—	9	2	1	—	—	4	—	—	1	4	24
22	—	—	—	—	—	—	13	—	10	2	5	1	—	—	—	2	33
<b>Total</b>	<b>32</b>	<b>3</b>	<b>1</b>	<b>12</b>	<b>150</b>	<b>37</b>	<b>259</b>	<b>44</b>	<b>41</b>	<b>65</b>	<b>8</b>	<b>12</b>	<b>64</b>	<b>728</b>			

**Table IV Professional Degree  
Class of September, 1968, February, 1969, June, 1969  
Placement by Field**

Course	Acad.		Res.		Teaching		Further Study		Industry	U.S. Gov't	Armed Service	For'gn Stud. Rtn Home	Misc.	Un-decided	Un-known	Total
	MIT	Other	MIT	Other	MIT	Other	MIT	Other								
1	1	—	—	—	—	—	2	1	4	—	2	2	—	—	1	13
2	1	—	—	—	—	—	8	—	2	—	1	—	—	—	1	13
6	3	—	—	1	—	—	29	2	10	—	5	3	—	—	3	56
10	—	—	—	—	—	—	1	—	1	—	—	—	—	—	1	3
13	—	—	—	—	—	—	3	—	—	4	19	2	—	—	1	29
16	—	—	—	—	—	—	1	—	—	1	1	—	—	—	—	3
22	—	—	—	—	—	—	1	—	2	—	2	—	—	—	1	6
<b>Total</b>	<b>5</b>	<b>—</b>	<b>—</b>	<b>1</b>	<b>—</b>	<b>—</b>	<b>45</b>	<b>3</b>	<b>19</b>	<b>5</b>	<b>30</b>	<b>7</b>	<b>—</b>	<b>—</b>	<b>8</b>	<b>123</b>

Table V Ph.D./Sc.D. Degree  
Class of September, 1968, February, 1969, June, 1969  
Placement by Field

Course	Acad. MIT	Res. Other	Teaching MIT	Teaching Other	Further Study MIT	Further Study Other	Industry	U.S. Gov't	For'n Stud. Rtn Home	Misc.	Un-decided	Un-known	Total
1	1	—	1	2	—	—	3	3	1	—	—	1	12
2	—	1	1	5	—	1	24	1	1	—	—	2	36
3	2	2	1	1	2	—	26	3	2	1	—	1	41
5	8	2	—	10	—	1	20	2	3	—	—	3	49
6	6	1	8	4	1	—	16	—	4	—	2	3	45
7	4	3	1	6	—	1	4	—	1	—	—	2	22
8	13	11	—	5	—	1	6	5	3	—	—	2	46
9	1	2	—	—	1	—	—	—	—	—	—	—	4
10	—	—	3	1	—	—	15	—	—	—	—	—	19
11	—	—	—	1	1	—	1	1	—	—	1	1	6
12	1	1	—	—	—	—	2	—	2	—	1	—	7
14	—	—	—	17	—	—	2	1	—	—	—	—	20
15	—	—	4	11	—	—	3	—	1	—	—	—	19
16	3	—	1	—	—	—	4	2	1	—	—	—	11
17	—	1	—	6	—	—	1	—	1	1	—	—	11
18	1	—	1	9	—	2	1	—	2	1	—	—	17
19	—	—	2	2	1	—	1	1	1	1	—	—	9
20	1	1	—	1	—	1	1	1	2	—	—	2	10
21	—	—	1	2	—	—	—	—	1	—	—	—	4
22	1	4	—	1	—	—	—	—	1	—	—	—	13
23	1	—	—	1	—	—	—	—	2	—	—	—	2
<b>Total</b>	<b>43</b>	<b>29</b>	<b>24</b>	<b>85</b>	<b>5</b>	<b>9</b>	<b>133</b>	<b>20</b>	<b>28</b>	<b>2</b>	<b>4</b>	<b>18</b>	<b>403</b>

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**Table VI Class of September, 1968, February, 1969, June, 1969**

**Placement Record at Graduation — How Job Contact was Secured**

<b>Placement interview at M.I.T.:</b>			
S.B.	S.M.	Prof.	Ph.D./Sc.D.
39%	27%	9%	17%
<b>By own letter of application from employers listed on the Placement Notices:</b>			
S.B.	S.M.	Prof.	Ph.D./Sc.D.
4%	1%	—	1%
<b>Through a faculty member:</b>			
S.B.	S.M.	Prof.	Ph.D./Sc.D.
9%	11%	6%	36%
<b>By direct solicitation:</b>			
S.B.	S.M.	Prof.	Ph.D./Sc.D.
29%	29%	26%	24%
<b>Through employment agency:</b>			
S.B.	S.M.	Prof.	Ph.D./Sc.D.
4%	2%	—	2%
<b>Other:</b>			
S.B.	S.M.	Prof.	Ph.D./Sc.D.
15%	30%	59%	20%

**Table VII Industrial Salary Offer Statistics<sup>1</sup> 1968-69**

Placement Bureau					
<b>SCHOOL OF ENGINEERING</b>					
			<b>LOW</b>	<b>MEDIAN</b>	<b>HIGH</b>
	S.B.	(230) <sup>2</sup>	705	845	935
	S.M.	(148)	815	990	1250
	Ph.D.	(64)	1150	1380	1580
<b>Aeronautics and Astronautics</b>					
	S.B.	(72)	755	820	875
	S.M.	(15)	815	975	1170
<b>Chemical Engineering</b>					
	S.B.	(19)	800	860	900
	S.M.	(23)	940	1000	1240
	Ph.D.	(14)	1190	1370	1500
<b>Civil Engineering</b>					
	S.B.	(8)	780	800	840
	S.M.	(7)	845	1010	1125
<b>Electrical Engineering</b>					
	S.B.	(91)	755	850	935
	S.M.	(45)	915	1000	1150
	Ph.D.	(24)	1150	1450	1580
<b>Mechanical Engineering</b>					
	S.B.	(21)	800	850	895
	S.M.	(39)	860	975	1250
	Ph.D.	(8)	1300	1400	1480
<b>Metallurgy and Materials Science</b>					
	S.B.	(18)	740	830	895
	S.M.	(11)	930	950	1020
	Ph.D.	(12)	1225	1325	1400
<b>ALFRED P. SLOAN SCHOOL OF MANAGEMENT</b>					
	S.B.	(16)	735	805	930
	S.M.	(20)	920	1075	1500
<b>SCHOOL OF SCIENCE</b>					
	S.B.	(33)	735	820	1035
	S.M.	(5)	915	945	1000
	Ph.D.	(53)	1100	1275	1500
<b>Chemistry</b>					
	Ph.D.	(43)	1100	1250	1410
<b>Mathematics</b>					
	S.B.	(18)	735	820	1035
<b>Physics</b>					
	S.B.	(13)	740	825	900
	Ph.D.	(8)	1150	1350	1500
<b>ALL COURSES</b>					
	S.B.	(281)	735	835	1035
	S.M.	(174)	815	1000	1500
	Ph.D.	(117)	1100	1335	1580

<sup>1</sup> monthly salary figures  
<sup>2</sup> number of offer letters

## OFFICE OF PUBLIC RELATIONS

During a year in which communication often assumed a position of urgency, the Office of Public Relations has sought to become more effective in its basic task. On occasion, when there has seemed to be an overload of information (and misinformation), its function has been a moderating one, directed toward elucidation rather than amplification.

In general, we have been guided by a conviction that the community acts most wisely when most fully informed. A new publication, *The Institute Report*, was launched as a means of conveying information, especially about academic affairs, to the community. *Impact* was issued experimentally to provide information about social service activities.

As the year came to an end, Paul E. Johnson, who has been Assistant to the Vice President and Secretary, was appointed Associate Director of Public Relations and Director of Campus Information Services. He has the responsibility for the Information Office, the Institute Calendar, and coordination of information for the community and its visitors.

Aside from campus protest, activities which attracted the greatest public attention to M.I.T. during the year were the Great Electric Car Race and the Instrumentation Laboratory's part in the Apollo program. Robert M. Byers, Associate Director, was directly responsible for the public relations aspects of these programs.

One project undertaken and completed was the making of a film, "M.I.T.: Progressions," specifically for use by the Educational Council and the Admissions Office in acquainting high school students with the Institute's concern for the humanities, the arts, and social issues — less widely appreciated than its preeminence in science and engineering. The cameraman-director was David Espar, '67, assisted by Mrs. Espar, who made the film as a master's thesis for Stanford University and sought to express, in the vernacular of the new generation, his own view of his alma mater. John G. N. Rushbrook, newly appointed Assistant Director of Public Relations, supervised the project and also gave special attention to publicizing the Institute's art activities and the Sloan School of Management.

William K. Stuckey, formerly a science editor at Northwestern University, joined the staff as Associate Director, assuming the editorship of *Reports on Research* and also undertaking the writing of *The Institute Report*. Miss Joanne Miller, editor of *Tech Talk*, *Safe Talk*, and *Impact*, was promoted to Assistant to the Director. As secretary, Mrs. Terri Freda performed superbly, especially in keeping internal lines of communications untangled.

In the Office of Publications, under the direction of William T. Struble, the number of publishing projects increased from 285 to 294 but at

the same time costs dropped from \$350,000 to \$258,276. The substantial decrease in costs reflects in part the tightening of budgets of clients for printing but also results, we believe, from increased efficiency in operations. Glenn T. Curtis, who had served effectively in coordinating transactions with printers, moved at the end of the year to the Purchasing Office to succeed Frederic W. Fenerty upon his retirement as buyer of printing.

Largely through the achievements of the graphic designers, Mrs. Jacqueline S. Casey, Ralph M. Coburn and Dietmar R. Winkler, M.I.T. maintained its leadership in contemporary communications graphics. A dramatic example of this leadership was given in the annual exhibition of the Type Directors Club of New York, in which an unprecedented 45 publications (a record for a single entrant) from M.I.T. were included among the total of 200 chosen from 1,800 entries.

The American Institute of Planners presented at its national conference a special display of M.I.T. publications, titled "Visual Communications in the Public Sector." *Graphics Annual* of Switzerland selected seven entries from M.I.T. for publication and the American Institute of Graphic Arts included M.I.T. publications in its annual exhibition. M.I.T. was represented by five publications in *Modern Publicity 68-69*, published in London and New York. Publications were included in *CA Annual* and the Mead "Creativity on Paper" exhibition. The American College Public Relations Association awarded a Special Merit citation for the "total publications program" of M.I.T.

Mr. Coburn served as designer for the issues of *Technology Review*, which received three awards for design from the Society of Publication Designers. His work was presented in a one-man show at the Alpha Gallery, Boston, under the title "Variables and Random Sequences." Mr. Winkler was a lecturer for two semesters in a publishing course at Simmons College.

FRANCIS E. WYLIE

### **OPPORTUNITY DEVELOPMENT OFFICE**

The Opportunity Development Office (O.D.O.) became operational in September, 1968, under the direction of James C. Allison Jr., former personnel recruiter for General Dynamics, and Director of Operations for the Opportunity Industrialization Center in Roxbury, with the specific mandate to suggest and promote methods of improving equal employment opportunities for M.I.T.'s current minority employees, as well as new hires.

To help Mr. Allison to carry out his tasks, President Howard Johnson created an Ad Hoc Task Force on Equal Employment, under the direction



of Dr. Jack P. Ruina, to review the employment work force and long range goals. A preliminary report, supplementing the Ad Hoc Task Force recommendations, has been submitted to the President. It included a five-year plan of implementation to increase the number of minority employees and afford wider opportunities for upward mobility of current employees.

The highlights of the Ad Hoc Task Force report included a training program in the clerical, lab technician, and maintenance helper categories, as well as new methods of recruiting and statistical record keeping for the personnel departments. The group also recommended that the personnel departments increase minority group representation on their staffs and that the O.D.O. conduct periodic reviews to help departments set up and maintain realistic equal employment goals.

The O.D.O., with the assistance of Joseph F. Lynch, former manager of Burton House, is responsible for the Compliance Reports to the Office of Federal Contract Compliance and the Equal Employment Opportunity Commission. Mr. Lynch has been providing counseling for the newly hired trainees who have little or no job related skills. This program is an experimental pilot project developed and carried out by the Committee on Job Training and Education.

The above volunteer group developed approximately nine job training positions and recruited young men through Mr. Lynch to fill lab assistant positions. The majority of the trainees have shown a highly successful work history, despite being handicapped by normally insufficient educational and job-related backgrounds. The insight gathered from this program will serve as a guide to the larger formal training program recommended by the Ad Hoc Task Force.

Other programs and recommendations, developed by the O.D.O. and presented for action, include an Equal Employment Booklet, Equal Employment Opportunity display booths, an employee attitude survey, implementation of an Electronic Data Processing system for all personnel records, exit interviews for all employees, and advertisement of office and hourly vacancies in *Tech Talk* or other M.I.T. official bulletins. In addition, the O.D.O. has recommended that the Lowell Institute become a two-year accredited college, that the present training office be renamed the Employee Relations Section, and that a new department of training, including a training officer, be established.

JAMES C. ALLISON JR.

## OFFICE OF PERSONNEL RELATIONS

With nonacademic employment reaching 7,701 in the middle of 1969, the Office of Personnel Relations continued to expand its services and

support for the M.I.T. community. In addition to widened programs in wage and salary administration, benefits, tuition assistance, professional recruitment, and the high school, secretarial school, and college recruiting program for office employees, the Personnel Office made important innovations in its minority employment and guidance programs; initiated orientation sessions for new employees; moved toward complete computerization of personnel records; and enlarged its information program for employees. Following is a brief account of some of the more significant developments during the year.

#### EMPLOYMENT LEVELS

At the close of fiscal year 1969, total nonacademic employment at the Institute had reached 7,645, an increase of .3 per cent over the year before. Employment increased on the campus 1.7 per cent to 4,068, decreased 3.1 per cent to 1,814 at the Instrumentation Laboratory, and increased .9 per cent to 1,763 at the Lincoln Laboratory. The modest overall increase of .3 per cent at the Institute continues the slower growth pattern and stabilization of employment which began to take effect in the first part of fiscal year 1968.

#### EQUAL EMPLOYMENT OPPORTUNITY

The Institute continued to make small but steady gains in minority employment during 1968, despite the overall decline in nonacademic employment. The percentages of minority employees at M.I.T. reached 5.7 per cent in 1968 as against 3.7 per cent in 1964, when M.I.T. first joined the President's Plan for Progress. Of these, 3.7 per cent were black as against 2.9 per cent in 1964.

The obligation to develop a more vigorous program of employment opportunities for members of the black community and other minority groups was emphasized by President Howard Johnson in his letter to the M.I.T. community on September 27, 1968. To insure concerted action toward this goal, he appointed the Ad Hoc Task Force under the chairmanship of Dr. Jack P. Ruina. Since that time, recommendations arising out of the Task Force's studies have led to this office's hiring of a qualified minority recruiter, two minority counsellors, and a training specialist for minority group employees. Additional indications of an escalation in the program have been a more liberal hiring policy for black employees and increased advertising in publications reaching black readers. The Office of Personnel Relations has also benefited from the assistance of the newly created Opportunity Development Office, which has strengthened M.I.T.'s ties with community agencies and has provided a counseling service for black employees.

## OFFICE OF PERSONNEL RELATIONS

### UNION RELATIONS

Negotiations with unions representing 2,400 Institute employees were concluded with agreements in the summer and fall of 1968. Agreement was reached on June 29, 1968, with the Building Service Employees' International Union representing maintenance and service employees; in October, 1968, with the union representing the dining service employees, and in the same month with the Research, Development, and Technical Employees Union (R.D.T.E.U.) representing technicians and other laboratory service employees. The new two-year agreements covering these employees provided a wage and benefit package which amounted to 6½ per cent increase in the first year and 5½ per cent increase in the second year, ending June 30, 1970. Other features of the agreements were an increase in the sick leave accrual and a number of noneconomic changes including an equal opportunity provision.

During the past year the Institute's and the R.D.T.E.U.'s joint classification commission was very effective in reducing and resolving a number of classification questions before arbitration.

### COMPENSATION PROGRAMS

In keeping with Institute policy of equitable and competitive compensation for its employees, general salary and wage structures of staff, office, and hourly personnel were analyzed during the year and adjustments made not only to maintain alignment with local and national patterns, but to keep pace with the inflationary trend. In addition, the wages and salaries of more than 6,000 employees were reviewed by their supervisors, and individual adjustments were made on a merit basis within the prescribed framework.

### OFFICE EMPLOYEES

Employment of office personnel continued to be extremely active in 1968, as over 3,000 applicants were interviewed and 884 were added to the Institute payroll. Efforts to improve employment attractions, in the face of high turnover, included increased vacation accrual, a full tuition reimbursement, and higher salaries. However, the Institute-wide turnover rate for office personnel in the fiscal year rose to a new high of 45.3 per cent as against 36.3 per cent for the previous fiscal year, and, there was a continuing trend toward fewer applicants to fill the numerous openings. Although attempts to raise the number of applicants through increased advertising and recruiting were by no means a failure, the shortage of office employees in the surrounding community is acute as witnessed by similar situations in other organizations and firms. Indications are that the intense competition for available appli-

cants and the associated high turnover will be critical factors for some time to come.

At the end of the fiscal year, a program for hiring office personnel from disadvantaged backgrounds was underway and had succeeded in placing over 30 young people in summer positions. It is hoped that this effort will lead to greater numbers of minority applicants in the future for full-time positions. The program is also an aid in widening the Institute's contacts with the local community, as the majority of the applicants were from Cambridge.

#### **ORIENTATION PROGRAM**

Another innovation during the year was the Orientation Program for office employees, a group which has a history of high turnover. A morning session for new employees includes a brief history of M.I.T., a description of the Institute's organization, an explanation of policies and procedures, a slide tour of the campus, and a film on office safety. In the first ten months of the program, 43 orientation sessions were attended by 500 employees, and their impressions of the program have been very favorable.

#### **PROFESSIONAL PERSONNEL**

Although employment at the Institute was generally slower last year, activity in the professional area increased significantly in terms of numbers of personnel recruited via an enlarged interviewing process and additional recruiting methods including advertising, the solicitation of a number of minority educational institutions, and other means, such as a conference seminar on data processing for the blind, which was funded by the Massachusetts Commission for the Blind.

In other activities of note during the year, several new surveys in salary administration were undertaken to determine proper levels of compensation, especially for administrative and data processing personnel. In addition, an informal committee was formed to discuss the various professional appointments at the Institute, their distinctions, and revisions where appropriate. Discussions are also being held to consider the need and format of a career planning and development program at the Institute.

#### **EDUCATIONAL ASSISTANCE**

As one means of attracting, retaining, and developing qualified personnel, the Institute since 1960 has offered financial assistance for job-related study. The Tuition Assistance Plan provides 100 per cent reimbursement of tuition and fees up to a maximum of \$400 a year for after-hours study.

## OFFICE OF PERSONNEL RELATIONS

For research and administrative staff members, an alternative is to take one course a semester during the day at M.I.T. or another college or university, with 75 per cent reimbursement. During the fiscal year 500 employees (9.0 per cent of those eligible) and over 400 staff members (18 per cent of those eligible) took advantage of this benefit.

With a view to making educational assistance more available and useful to all employees, particularly at the lower skill levels, where many from disadvantaged minority groups necessarily begin and may find advancement slow, the Personnel Policy Committee and the administration approved a recommendation that assistance be extended to courses that would help an employee qualify for transfer to work in fields offering enhanced promotional and career opportunities.

### COMMUNICATIONS AND COMMUNITY RELATIONS

The Office of Personnel Relations invited executive and administrative officers from Institute laboratories and departments to take part in a series of meetings during the year. The forum was of value in the working out of common policy and helped to increase effective communications between the officers and the Institute administration.

An important contribution to improved communications is the computerization of personnel records. Progress was made toward this goal during the year as the Office of Personnel Relations began working closely with the Office of Administrative Systems in preparation for integration of these records into a management information system.

Increased efforts were made to inform present and prospective employees about the Institute and their job. All new employees are individually advised by a personnel representative about their benefits, working conditions, services and activities of the Institute. A handbook for new employees was published in January and sent to all office and hourly personnel. Currently, the supervisors manual for the hourly and office groups is being revised and will be completed during the coming year. Also near completion or in progress are handbooks, employment brochures, and policy and procedures manuals for professional personnel.

The Office of Personnel Relations was involved again during the year with the United Fund Drive, the Red Cross Blood Drive, and other volunteer efforts. Contributions to the United Fund exceeded \$133,000 from all members of the community, and the Blood Drive was the most successful ever at the Institute. The donations of faculty, students, and employees totaled 2,013 pints, a record which was recognized by an award from the Massachusetts Red Cross Blood Program.

ROBERT J. DAVIS



## **VICE PRESIDENT, RESEARCH ADMINISTRATION**

**S**everal administrative units at M.I.T. report to the President through the Vice President, Research Administration. These include the libraries, the Summer Session, the Operations Research Center, the M.I.T. Press, the Francis Bitter National Magnet Laboratory, the Cambridge Electron Accelerator, and the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University. Reports from the director of each of these units follow. No particular comments on each unit are required on my part, since each report is complete and comprehensive.

Emphasis, however, should be placed on the problem of the libraries. These are emphasized in detail in the report of the director. No practical solutions are evident at this time except the construction of more space and increased budgets for acquisitions. However, the huge volume of literature generated each year, which must be made available to our faculty in some convenient form, makes it unreasonable from a fiscal standpoint to consider that simply supplying more space and buying more volumes is the right answer. Several groups in the country are wrestling with these problems, and the hope is that some reasonable solutions to relieve the pressures will be developed in the not-too-distant future. These efforts need much better support.

On a happier note, the M.I.T.-Harvard Joint Center for Urban Studies has completed its tenth year of highly successful operation. Congratulations and expressions of appreciation are due to the three directors who, during this period, contributed much to giving the Joint Center a worldwide reputation as the leading institution in its field. Martin Meyerson, now President of the State University of New York at Buffalo; James Q. Wilson, now Professor of Government and Chairman of the Department

of Government at Harvard University; and Daniel Patrick Moynihan, now Special Assistant for Urban Affairs in Washington. To this list should be added several others but particularly Professor Lloyd Rodwin, who for ten years served brilliantly as Chairman of the Faculty Committee for the Joint Center.

We were very fortunate in persuading Professor Robert C. Wood, Head of the Department of Political Science at M.I.T., to take over the leadership of the Joint Center in February following the resignation of Professor Moynihan. Professor Wood had just completed a tour of duty in Washington as Undersecretary of Housing and Urban Development and, finally, Secretary of Housing and Urban Development. Professor Wood has already demonstrated that our choice was a happy one. Under his direction the Center will continue to make new and important contributions to the field of urban affairs, which, of course, is becoming increasingly recognized as vitally important for the solution of major national problems.

Finally, I should like to make special mention of two other highly successful operations at the Institute, where the success has been largely due to the imagination and dedication of the directors. These are the Summer Session, under the direction of Professor James M. Austin, and The M.I.T. Press, under the direction of Carroll G. Bowen.

CARL F. FLOE

### **FRANCIS BITTER NATIONAL MAGNET LABORATORY**

The year was marked by steady progress on existing programs and the emergence of a wealth of new ideas in both basic and applied areas of high magnetic field science. These promising developments were, however, accompanied by increasing frustration over the lack of financial support for new projects. The Five Year Plan for the Laboratory, completed this year, calls for expansion of the high field facility by utilization of the hybrid magnet concept, which involves a combination of superconducting and water-cooled solenoids. In addition, it outlines a number of very promising new avenues for basic research and proposes that work be started or expanded on several possible applications of high magnetic fields. These fields include synchrotron radiation sources, hot plasma containment, high resolution nuclear magnetic resonance, electromagnetic proof loading of bonded aircraft structures, and magnetic guidance of catheters in the human body. It is hoped that the implementation of the Five Year Plan or at least several of its major segments will be initiated in the coming year.

Several applied programs, supported by a number of small grants and contracts, are already under way. The magnetically guided catheter system



developed at the Laboratory has been successfully used at the Massachusetts General Hospital. Construction of an improved system awaits further funding. A pulsed magnetic field method for nondestructive testing of bonded aircraft structures has been tested and a more advanced system is being built. A magnetic separator for removing impurities from kaolin, a clay used in paper making, has been developed. A full-scale production model is being built by an industrial concern. Dr. David Cohen, formerly of the University of Illinois, is building a magnetically shielded room at the Laboratory to continue his studies of the very weak magnetic fields of the heart, brain, and abdomen.

The power of high magnetic fields, as tools for basic studies of the properties of matter, continues to be demonstrated by both our own programs and those of outside users of the magnet facility. New data on tellurium from cyclotron resonance measurements at submillimeter wavelengths have shown the need for a new theoretical calculation of the band structure. Stress modulation techniques in magneto-optical absorption experiments have provided new information on the band structure of PbTe, GaSb, and InSb. Far infrared studies of solid-state plasmas have provided greater insight into the plasma-phonon interactions in semiconductors, leading to a many body quantum theory of such systems. Cyclotron resonance measurements of the polaron mass in CdTe have been made with far infrared laser sources and fields up to 200 kilogauss. A first-order phase transition in  $\alpha\text{Fe}_2\text{O}_3$  at 77°K has been studied by observation of the magnetic susceptibility and ultrasonic attenuation. An extensive series of measurements on the magnetic properties of palladium and its alloys has been made. Magnetic interactions in these materials are of great interest because pure palladium is nearly ferromagnetic and alloying moves the system toward or away from the ferromagnetic state, giving a detailed insight into the mechanisms of ferromagnetism. A theoretical study of conduction electron spin polarization in dilute ferromagnetic alloys has led to a successful analysis of neutron scattering data in PdFe and PdCo. Magnetic susceptibility measurements on cerium magnesium nitrate indicate that it has a phase change to an antiferromagnetic state in the millidegree Kelvin range. This material is commonly used to produce extremely low temperatures by adiabatic demagnetization, and its magnetic properties must be known accurately to allow measurement of the absolute temperature.

Progress on the hybrid magnet has been slowed by nonuniform dimensional properties of the superconducting ribbon. The difficulty has been overcome and initial testing will begin soon. The reliability and lifetime studies of phonon-plasma interactions in solids. Proposals for joint pro-solid state division of the Lincoln Laboratory.

Visiting scientists continue to use about half of the total magnet operating time. A group from Brandeis University observed nuclear resonance of the proton at 130 kilogauss. This is the highest field at which nuclear resonance has been observed. Other visitors from throughout the world made important contributions to knowledge in many fields of science.

The Laboratory's interaction with the academic departments has increased. A graduate seminar on solid-state topics, arranged by Professor Mildred S. Dresselhaus in conjunction with Professors Benjamin Lax and George W. Pratt, was held alternately at the Laboratory and at the Center for Materials Science and Engineering. Three staff members had teaching responsibilities in the Department of Physics. Two doctoral theses, one Electrical Engineer thesis, two Master's theses, and six Bachelor's theses were completed during the year. A joint program with Professor Clifford G. Shull's group has been started on neutron diffraction studies of phonon-plasma interactions in solids. Proposals for joint programs with Professor John S. Waugh of the Department of Chemistry on high field nuclear magnetic resonance and with Professor Bruno Coppi of the Department of Physics on high field plasma containment studies have not yet been funded. The Laboratory continues to work closely with the solid state division of the Lincoln Laboratory.

Dr. Brian B. Schwartz was appointed an associate professor in the M.I.T. Department of Physics. He will retain his position as leader of the theoretical physics group of the Laboratory. Professor Lax was elected to the National Academy of Sciences. He also received the Gano Dunn Medal for outstanding professional achievement by an alumnus of Cooper Union and was appointed a member of the Visiting Committee for the Physics Department of Stevens Institute of Technology. Dr. Simon Foner was appointed a member of the Visiting Committee for the Physics Department of Carnegie-Mellon University. Dr. D. Bruce Montgomery has been appointed a member of the Technical Committee on Superconducting Material and Devices of the Institute of Electrical and Electronics Engineers. Dr. Montgomery's book on the design of high field magnets, published in June, promises to become the standard work in the field.

BENJAMIN LAX

### **CAMBRIDGE ELECTRON ACCELERATOR**

The Cambridge Electron Accelerator Laboratory has continued to explore the physics of high-energy electrons and photons. During the period of this report, research groups composed of staff members and graduate students from M.I.T., Harvard University, and other institutions worked on 16 experiments including, among others, the elastic scattering of pho-

tons, the production of  $\pi^-$  and  $\pi^+$  mesons with polarized photons, the photoproduction of  $\pi^0$  from the neutron, the scattering of electrons from hydrogen and deuterium, and the production of muon pairs at high mass values.

In parallel, an exciting development program has been carried out whose ultimate goal is to produce head-on collisions between 3-BeV electron and positron beams rotating in opposite directions in the accelerator ring. This will permit studies of the basic electromagnetic interaction up to an effective energy of 6 BeV, a value higher than has been available until now. An important advance in accelerator technology was achieved by completion of the Bypass into which the circulating beam is switched after acceleration.

KARL STRAUCH

### DIVISION OF SPONSORED RESEARCH

During the past year, no Institute activity received greater attention than the sponsored research programs conducted on campus and at the two special laboratories. The critical evaluation and assessment of the policies and practices underlying these programs, particularly those sponsored by military departments, involved the active participation of faculty, students, alumni, and administration, and attracted the interest and attention of Federal sponsors and Congress. Needless to say, M.I.T. was not the only university undergoing this type of review.

Another development having nationwide impact was the reduction in the overall level of Federal research support. This resulted generally from budgetary pressures created by the Vietnam war, and specifically from the fiscal 1969 expenditure ceiling that Congress imposed on Federal agencies as the price for enacting the surtax. As Federal agencies sponsoring research at M.I.T. responded to the expenditure ceilings imposed on them, the Division (D.S.R.) kept individual faculty members, departments, schools, and laboratories continuously informed of the relation of their expenditures to budgetary limitations or reductions imposed in turn on their programs. The Division also developed data to support requests for additional funding or for relief from budget ceilings which threatened to impair seriously any of the Institute's basic research and educational programs.

### ADMINISTRATION OF BUDGET CEILINGS

Most Federal research sponsors reduced expenditures by renegotiating grant budgets downward, by reducing the level of support on continuing

programs, or by dropping programs entirely. The National Science Foundation (NSF), however, imposed a ceiling on total cash expenditures under all active NSF grants (with some exceptions) at each grantee institution, regardless of when such grants had originally been awarded, thereby transferring to M.I.T. and other grantees the total responsibility for deciding how to allocate the required reductions. From a purely administrative point of view, this approach resulted in the most difficult problems for the Institute and the Division of Sponsored Research.

The Foundation based its expenditure ceilings for each institution essentially on the prior year's expenditures and estimated that the required reduction for most grantees would be approximately 17 per cent for fiscal 1969. However, due to the rapidly increasing volume of NSF support at the Institute, this would have meant a reduction of 31 per cent in our planned NSF expenditures for fiscal 1969. Furthermore, since the ceiling was not imposed until the year was well under way, the effective reduction as applied to expenditures for the balance of the year was close to 40 per cent.

After obtaining a revised estimate of anticipated fiscal 1969 expenditures under NSF programs, the Institute felt that it could not ask the departments, laboratories, and centers to reduce their NSF expenditures more than 20 per cent below that revised figure without doing irreparable damage to Institute research programs. Therefore, a well-documented appeal was made to NSF. It resulted in an increase in the M.I.T. expenditure ceiling to within a few percentage points of the revised fiscal 1969 M.I.T. budget, as reduced by the 20 per cent. A further deferring of expenditures in selected programs during the year brought expenditures down to meet the ceiling by the end of the year.

While the foregoing process can be stated simply, it involved the establishing of ceilings by school, department, and individual research project, the meticulous following of expenditures project-by-project, the compilation of these into overall budget versus expenditure presentations to department heads and laboratory directors, the periodic adjustment of ceilings to reflect variations from expected spending rates, and preparation of data to support requests for additional program funds and an increase in the overall expenditure ceiling.

This was the broadest and most detailed effort in overall financial management, coordination, and fiscal control in which the Division has participated, and a great deal was learned from it.

**VOLUME**

The total volume of sponsored research performed in fiscal 1969 by the academic departments and interdepartmental laboratories and adminis-

## DIVISION OF SPONSORED RESEARCH

tered by the Division showed no significant increase over the fiscal 1968 figure of \$55,838,000. This leveling off follows more than ten years in which research volume has increased 10 per cent or more annually. Moreover, with inflation in the national economy simultaneously rising to more than 5 per cent per year, this leveling off actually represents a reduction in the research performed.

Total research support from Federal agencies in fiscal 1969 dropped by about \$1,000,000 from the level of 1968. This was primarily due to the ceiling imposed on expenditures by the National Science Foundation. The Federal reduction was offset by an equal increase in support from private foundations, notably the Ford Urban Grant. Industrial support fell to a little more than 3 per cent of total sponsored research, but this figure does not include industrial support for new buildings or the Industrial Liaison Office programs.

The School of Architecture showed an increase of 100 per cent over fiscal 1968, reflecting greater interest in urban problems throughout the nation. However, this increase was more than offset by decreases of 2 per cent to 3 per cent in the Schools of Science and Engineering. The School of Humanities and Social Sciences and the Sloan School increased by more than 10 per cent, while the interdepartmental laboratories showed a slight decrease in fiscal 1969.

### INDIRECT COSTS

The general leveling-off in research volume in fiscal 1969 was matched by a growing austerity in on-campus expenditures. This, coupled with a number of refinements in accounting procedures, is expected to result in a final fiscal 1969 indirect cost rate of approximately 46 per cent on campus, compared with the previous year's rate of 49 per cent. This reduction in the indirect cost rate during a period of reduced research support is due in part to restraints imposed on indirect costs.

Indirect costs on research programs at educational institutions were the subject of a study during fiscal 1969 conducted by the General Accounting Office (GAO), at the request of Congress, with the specific goal of determining the feasibility of applying a uniform indirect cost rate to a wide range of organizations and activities. Wide variation in organization, procedures, and kinds of effort among educational institutions themselves, in addition to the difference between such institutions and industry, led GAO to conclude that this is neither practicable, equitable, nor correct in principle.

### CLASSIFICATION RESTRICTIONS

Proposed restrictions on the free dissemination of research results created problems on projects sponsored both by the Federal government and in-

dustry. The most troublesome was the imposition by the Department of Defense (DOD) of export controls on distribution of unclassified reports, so that each transmission of such a report to a foreign national, including foreign national students and staff members at the Institute, required the prior approval of the sponsor. The impact of this requirement on M.I.T. was described in material submitted to DOD, and subsequently used in a compilation prepared within DOD for review by the Secretary of Defense. In addition, the Institute's policy and practice with regard to undertaking classified research programs was subjected to close scrutiny by students, faculty, and administration, particularly in connection with programs conducted by the special laboratories. This has also become a matter of interest to Congress and Federal sponsors, as the question of research supported by military departments, especially that which is classified, has become a subject of national debate.

#### FACILITIES PROGRAM

The largest facilities project now under way is the \$12,900,000 Electrical Engineering and Communications Research building, which is well into the planning stage. In fiscal 1969, the Institute accepted a Federal grant of \$750,000 in support of the project under the Undergraduate Facilities Program of the U.S. Office of Education, an additional \$300,000 from the Graduate Facilities Program of the same agency, and a \$750,000 grant under the Graduate Science Facilities Program of the National Science Foundation.

The Camille Dreyfus Building for graduate research in chemistry, funded in part by a National Science Foundation grant of \$2,900,000, is under construction with completion expected by the fall of 1969. Two projects begun in 1967 and now substantially completed are the renovation of the Engineering Library, funded one-third by the U.S. Office of Education, and the construction of the 400-MeV linear accelerator facility in Middleton, Massachusetts, for which the Atomic Energy Commission (AEC) has provided \$4,600,000 and the Institute approximately \$1,000,000. This facility has been partially occupied and the installation of accelerator components and equipment will commence in the summer of 1969.

#### EDUCATION AND TRAINING PROGRAMS

In 1969, Federally sponsored fellowships and traineeships decreased slightly from the fiscal 1968 level to approximately 785, providing \$4.1 million in support.

The National Science Foundation was again the largest sponsor, providing more than \$1.8 million in support of 386 students, roughly the

same level as the previous year. Also unchanged was National Institutes of Health (NIH) support of \$1.1 million for 190 fellowships and traineeships.

The Office of Education's National Defense Fellowship Program provided \$712,000 in support of 137 M.I.T. Fellows, a slight increase over 1968, but of this number only 36 were new awards as opposed to 65 in 1968. In addition, the National Aeronautics and Space Administration (NASA) Traineeship Program was reduced last year to \$168,000 in support of 24 trainees and will phase out completely next year with the nine remaining students. However, M.I.T. has agreed with NASA to use some \$60,000 of unexpended funds from past allocations to create six new traineeships of three years duration, each with partial stipends of \$3,000 annually.

The NASA International Fellowship Program, which brings students from other countries to study at M.I.T., supported six recipients in fiscal 1969 with eight recipients projected for next year. Housing and Urban Development fellowships are the only ones showing a significant increase, from support of three fellows in 1968 to seven in 1969 and 11 anticipated for 1970.

Finally, the Atomic Energy Commission provided \$185,000 to support 34 fellowship recipients in fiscal 1969 with 34 fellows anticipated in 1970.

#### **HEADQUARTERS, D.S.R.**

The Division used its fiscal 1970 budget review as an opportunity to reorganize D.S.R. headquarters budget procedures and to restructure its chart of accounts. The separation of the headquarters budget into individual budgets for each functional group within Division headquarters should gain better expenditure control.

The need for more rapid information retrieval has caused us to increase our use of data-processing technology. Computer programs started last year are either functional or partly so and are constantly being fed information necessary for building this year the files needed in the near future.

The D.S.R. property office is building a data bank for use in satisfying various requests for equipment inventories, such as those requested by the AEC. Currently there are some 28,000 items in the file which were acquired during the last two years in connection with programs sponsored by DOD, NASA, NIH and other agencies. It is estimated that we have some 70,000 sponsor-provided equipment items at the Institute.

A far-reaching program now on line at the Information Processing Center is the D.S.R. proposal file. All proposals submitted through the Division are being entered in this file which, linked with the Accounting

Office file, is a potential source of information ranging from the response patterns of individual sponsors to comparisons of budgeted with actual expenditures. At present there are some 1,300 proposals on file and these are updated every two weeks.

It is hoped that in two years we will have a complete on-line system offering, either by cathode ray display or computer print-out, statistical data most needed for the management of our accounts in a depth and format not presently available.

#### **D.S.R. REORIENTATION**

With regard to the internal organization and functions of the D.S.R. office, one of the most significant developments of 1969 was the realignment of responsibilities among the assistant and associate directors. The Division will be organized to provide administrative support for sponsored programs in the various schools, departments, laboratories, and centers in a manner that more nearly parallels the Institute's organization. Thus, it is hoped that the Division can be more responsive to the general trend of the Institute toward assigning greater administrative responsibility to each operating unit, including budgeting and financial management, and can cope more effectively with the cost-sharing requirements of the Federal government.

In addition, this will establish the organizational framework within which the Division can, at some point in the future, provide management support to activities other than the sponsored programs with which it is now concerned. Such a development seems inevitable, in view of the increasing integration of instructional and research programs within the framework of the schools and departments, and the trend toward greater financial interdependence between the two activities.

It is our intent that the Division be so organized and its outlook and orientation sufficiently broad that, as the need develops, it can provide financial and business administration support well beyond that required by traditional sponsored research programs.

STUART H. COWEN

#### **JOINT CENTER FOR URBAN STUDIES**

This is a year of special reckoning for the Joint Center for Urban Studies. It marks the end of the first decade of activity — and the beginning of the second. Midway in the academic year, its leadership changed. Daniel Patrick Moynihan responded to the call for national service by the incoming Administration in Washington, and I was liberated by the con-



clusion of the past Administration. Lloyd Rodwin, who has been a force for activity, scholarship, and continuity in the Center since its inception, asked to be relieved of his duties as Chairman of the Faculty Advisory Committee. Charles M. Haar of the Harvard Law School, who had just resigned after distinguished service as Assistant Secretary of Metropolitan Development in the U.S. Department of Housing and Urban Development, replaced him.

One follows in the footsteps of Pat Moynihan with trepidation, all the more so since his predecessors, Martin Meyerson and James Q. Wilson, had as surely and successfully led the Center. It is clear that the last few years have brought unprecedented attention to the Center, respect for its publications, and regard for its evaluations of public policy and program. Unquestionably, the Center has achieved the status of a national and international institution in urban affairs; and unquestionably, its work needs to be continued and expanded.

As it enters its second decade, it is appropriate for the Joint Center to consider anew in which directions, at what level of resources, and toward what objectives it should proceed. When the Center began, urban affairs commanded neither high attention in scholarship nor public concern. Accordingly, the policies the Center's first stewards adopted, of support, encouragement, and even enticement of faculty and students to the consideration of urban affairs were well conceived and executed. Now, the United States has belatedly begun to honor its commitment to the city, and "the urban crisis" is high on every national agenda. So it is proper now to summarize the record not as history but as a basis for responding more effectively to new needs and new responsibilities of scholarship. This report undertakes that assignment, dealing in turn with the accomplishments of the Center up to now, a prospectus for the future, and the organizational and financial arrangements that will be required.

#### THE FIRST TEN YEARS

As the Joint Center enters its tenth year, it is clear that it has acted as a successful leaven to the two universities, bringing about what is now a widely accepted, indeed lively, interest in urban studies. Specifically, the Joint Center has:

1. Enriched teaching faculties with promising young urbanists. Some have been brought here from other universities under cooperative arrangements with university departments; others have been home grown from among the Joint Center Fellows. (Harvard and M.I.T. currently have 12 faculty members in seven different departments or schools who are former Joint Center for Urban Studies Fellows.)
2. Stimulated the development of courses in urban affairs. In 1959, when

we began, Harvard's various school catalogues listed 13 courses concerned with urban affairs; M.I.T.'s catalogue listed 22. Today, the M.I.T. and Harvard catalogues each include more than 100 such courses. While the Joint Center can by no means claim sole responsibility for this explosion of urban studies within the universities, it would be unduly modest for us to deny having lit some of the fuses.

3. Provided facilities and money for urban research. More than 117 research projects have been sponsored, most by graduate students and junior faculty.

4. Contributed to the general pool of university scholarship. Twenty-eight books and 9 monographs have been published under our auspices. Our journal reprint series contains a listing of 91 articles. Reports were issued on the politics of 22 cities.

5. Brought men outstanding in urban affairs to Cambridge. By now the Joint Center has a long tradition of bringing people to Cambridge who are in the forefront of urban affairs at any particular time. We provide opportunities for students and faculty members alike to meet and discuss with such people in small informal groups, as well as scheduling more formal meetings.

6. In Ciudad Guayana, Venezuela, conducted an unusual experiment in the application of university skills and knowledge to an urban undertaking critical to the continued development of a great nation. For six years, a dedicated project staff worked in Venezuela in the planning of the new city and in developing policies for its implementation. There has been a continuing flow of scholarly work from that effort.

#### NEXT STEPS

We plan to continue making contributions in areas like these in the years ahead, but we wish to add some quite specific new kinds of resources, in three principal ways:

First, we expect the Center to function as a mobilizer of talent and information and other resources which enhance the capabilities of both universities and selected other organizations to discharge their urban responsibilities. As one example in this direction, our new survey research capability is now available for use by all university schools and departments. The first annual Boston Area Survey has been conducted, and the second is now being developed.

Second, the Center should begin collaborative research on a systematic, program basis in fields that engage the interests and skills of faculty members from both institutions. The beginnings of such structured development are already under way: Professor Lee Rainwater joins the Harvard

Department of Social Relations in the fall of 1969 and brings to the Joint Center for Urban Studies his National Institute of Health (NIH) project research focusing on urban family structure.

In the future, we also hope to take greater advantage of the combined resources of Harvard's professional schools and M.I.T.'s technological laboratories. For example, we want to consider the sustained involvement of the Joint Center in an important urban development, possibly focused on the creation of a new community. This summer work is under way in New Jersey on a specific site study. Since the Guayana experience gives the Joint Center for Urban Studies a unique capability in this area, we think such a focus could engage the many disciplines and talents of the two universities in a truly comprehensive way.

Finally, we believe the Center can and should link the resources of the urban academic community more systematically to important constituencies in the urban world at large, transmitting new knowledge to them rapidly and responsibly.

These are the directions in which the internal review and evaluation of the Joint Center for Urban Studies have taken us since January, suggesting how it can supplement, strengthen, and complement the urban resources and capabilities of Harvard and M.I.T. in full recognition of the rapidly developing interests in both universities. One basic plan must be to augment the capabilities emerging in academic departments and schools and to undertake those activities that the institutions find difficult to pursue alone. It is on that basis that we have begun our present prospectus and considered the changes in structure that might follow.

#### ORGANIZATION AND FINANCING

Up to now, the work of the Joint Center has been carried out largely by Harvard and M.I.T. faculty members on part-time salary arrangements, and by doctoral fellows. In addition, at any one time, there have usually been one or two full-time professional people associated with the Center, at least ten research assistants, and a small secretarial and administrative staff.

The device of supporting part of a faculty member's salary to enable him to devote a corresponding portion of his time for urban research served the original purposes of the Joint Center well. The money spent for such faculty salary support not only helped individual scholars to think and write about urban questions but also succeeded in involving, directly or indirectly, their university departments more closely with urban affairs. For example, a number of faculty members were attracted to Cambridge by cooperative arrangements between the Joint Center and their departments.

Today, however, new sources are available to support faculty salaries for urban research projects, and the sustained urban activities at the two universities have been substantially expanded. As we look ahead toward the new goals for the Joint Center, it is apparent that a new organizational pattern is required. With the present allocation of funding for underwriting faculty salaries, we find ourselves greatly constrained from taking advantage of the new kinds of opportunities we might otherwise be pursuing.

Almost every day's mail brings the Joint Center an opportunity to undertake a new activity which could in some way advance the state of the art. It is a discouraging fact of life at the Joint Center that most such requests for assistance have to be denied. We simply do not have the staff at our command to do the work. At the same time sizable numbers of Harvard and M.I.T. graduate students in urban studies come to us as they approach the end of their doctoral work in the hope of finding an association that will allow them to translate some of their new expertise into practice. In addition, many extraordinarily able people not presently connected with the universities would also like to be associated with the Joint Center. We should be able to make a better match between the work that needs to be done and the people who are available to carry it out.

#### CONCLUSION

The Joint Center for Urban Studies began at a time when scholars were uncertain whether or not there were genuine urban problems; public officials were indifferent to them; and the public at large was unaware of them. Times change, and it is fair to say that no field of academic inquiry is now more fashionable, no policy debate so eloquent, no area of public attention so pertinent as that of our urban condition.

The prescience that M.I.T. and Harvard displayed in establishing, nourishing, and supporting the Center now makes possible a time of great potential contribution to the national welfare. I am pleased to have become a part of the Center, and I look forward to the next years of accomplishment that will justify the work and the energy, the skill and devotion of my predecessors.

ROBERT C. WOOD

#### LIBRARIES

The past year has been one of planning more than execution — planning for growth in new directions, for better selectivity in collecting, and for more efficiency through the application of computer control of inventory.

## LIBRARIES

### GROWTH

The mounting flood of literature in every field is a perennial problem, and there is still no solution in sight other than building more shelves. Our collections at M.I.T. have been doubling in size every 12 years since the late fifties. That is twice as fast as the previous rate of growth. At the same time, our financial needs keep climbing. With these considerations in mind, last year Provost Jerome B. Wiesner brought together an ad hoc Committee on the Libraries, composed of deans and top administrative officers, and the group met several times this year. The first subject considered was requests from the Departments of Chemistry and Physics for reading rooms to provide quiet, attractive places where their faculty and graduate students could work with the literature. The proposed locations were 4,500 square feet which had been set aside in the new chemistry building, and 6,325 square feet formerly used as a computation center on the ground floor and in the basement of Building 26. A subcommittee composed of the Dean of Science and the Director of Libraries studied the requests and reported back to the full Committee. The report recommended that the proposals of the Departments be accepted with minor modifications. They were, and throughout the winter detailed planning was carried on by committees composed of departmental and library representatives.

Both reading rooms should be in operation early in the fall. According to current plans, the Chemistry Reading Room will be almost entirely on microfilm. It will have 45 journals back to the first year of publication. Only current numbers will be on paper and they will be replaced at the end of each year with film. In addition, there will be 1,500 books to start. It is not planned to have books on film. Principally organic chemistry will be covered at first, though there is a possibility that this may be expanded to include biochemistry and some aspects of biology.

The Physics Reading Room will absorb the collections of the Laboratory for Nuclear Science, adding books and journals in the fields of solid-state and space physics, astronomy, and materials science. This will be a more conventional reading room with 60 journal titles and 3,300 books and bound journals. One unusual feature will be a current collection of preprints, to be kept small and up to date by discarding each preprint as soon as it has been published.

The Science Library will continue to have the large basic and historical collections and to support course work. It will also be the center for interdisciplinary research. Mathematics, physical sciences, life sciences, and a number of other fields are conveniently located together. The two reading rooms should reduce activity in the Science Library, as they will be more convenient for the faculty and students of the two departments. They will

VICE PRESIDENT, RESEARCH ADMINISTRATION

Table	Volumes Added			Volumes in Library		Volumes Loaned	
	1967/68	1968/69	1967/68	1968/69	1967/68	1968/69	
Archives	753	2,235	18,627	28,126	—	—	
Dewey	31,662	25,691	248,592	274,557	77,694	81,491	
Engineering	10,292	9,911	146,623	148,136	49,795	47,297	
Aero & Astro	4,181	5,786	68,923	75,102	10,055	10,797	
Materials	210	396	699	1,083	2,250	1,725	
Space	1,186	1,449	6,297	7,752	1,558	1,932	
Humanities	10,843	10,436	176,275	181,053	36,373	37,429	
Music	639	1,255	12,841	14,153	3,808	5,115	
Reserve Book Room	—	—	—	—	10,681	12,014	
Rotch	5,663	5,049	65,140	69,294	19,861	23,749	
Science	8,241	8,227	279,233	289,207	55,200	56,644	
Lindgren	1,806	1,969	18,161	20,720	4,588	5,315	
Student Center	3,652	3,626	17,167	20,095	—	—	
<b>Total</b>	<b>79,128</b>	<b>76,030</b>	<b>1,058,578</b>	<b>1,129,278</b>	<b>271,863</b>	<b>283,508</b>	

LIBRARIES

be composed entirely of duplicates of material in the Science Library. So, although they will provide for more readers, they will not relieve the pressure for shelf space in the Hayden Building.

Input of books into all the libraries continues to grow. It varies directly with the rate of publication and the expansion of teaching and research programs, inversely with costs. Some authorities say the rate of world publication is going up 10 per cent a year. As to the coverage of teaching and research at M.I.T., it broadens each year, but it is too intangible to get a percentage figure. From 1957 to 1967 the price index for hard-cover books rose from 100 to 151.0 and periodicals from 100 to 163.0. In 1968 these indices were, respectively, 160.1 for books, 175.8 for periodicals. From 1957 to 1967 the overall price index rose from 100 to 116.3. The 1968 overall index is not available.

Our fastest growing library continues to be Dewey. The following table shows the projected number of volumes for the next five years:

Year (as of June 30)	Projected number of volumes
1969	200,000 (actual)
1970	227,000
1971	255,000
1972	284,000
1973	313,000
1974	344,000

These projections are conservative. They indicate that the rest of the second floor of the Hermann Building will soon have to be filled with stacks. Even this space will contain the library only until January, 1972, as shown by this table:

By adding	Total volume capacity becomes
One seminar room	214,000
One classroom	227,000
Second classroom	240,000
Third classroom	253,000
Second seminar	267,000

The above projections are in "working" capacity, two-thirds of "absolute" capacity. Going from one to the other involves increasing inefficiency of operation up to the point of complete asphyxiation when every shelf is full. Space for class and seminar rooms now located on the second floor will have to be found elsewhere. This development was anticipated when the building was designed. The time has arrived when it should be programmed.

The Rotch Library is full now and has been for three years. The staff has

been weeding old materials from the shelves, sending them to storage or disposing of them in order to make way for new purchases. A questionnaire sent to students in the School of Architecture and Planning in May, asking their reaction to the library, may be summarized as follows: "excellent for browsing and required reading but that is the end of it. . . . Those studying in the fields of science and technology are given great labs and research tools, but the tools and inspiration of the humanist, books, journals, and other documentation are found here only sparsely."

In short, Rotch Library is in desperate need of more space and more money to provide adequate collections. We are building a faculty and a student body in several fields such as urban studies, but the library provides no access in depth to the needed materials in art history, sociology, psychology, and economics.

A number of steps have been taken during the year elsewhere to remove less used materials to more remote locations. Crowding in the basement stacks of the Hayden Building was substantially reduced by sending some 12,000 volumes to New England Deposit Library, thus filling up all our space there. In the Hermann Building, a basement area which had been made available to the Dewey Library was fitted with high, closely spaced stacks for low use materials. Both of these moves run counter to our policy of keeping all except rare books on open shelves. In looking ahead, we see that unless we are able to build substantial new library facilities, we shall have to move more and more volumes to inconvenient, rented space. Predictions made this year show that we shall have to build or find shelving in each of the coming years as follows:

Year ending June 30	Number of volumes
1971	38,000
1972	38,000
1973	40,000
1974	60,000
1975	60,000
1976	60,000

Another area of rapid growth is Archives. Up to the present, insufficient space has been available to collect theses, records, and historical materials which have been stored in various Institute offices. Work space has been scarce, exhibit space nonexistent, so no real effort has been made to bring together those papers that should be retained by the Institute to document its own history. Moreover, there has never been a clear policy as to who owns what. Are certain classes of papers official Institute property, as opposed to department or laboratory property? Another necessary policy decision is how long administrative and academic offices may hold



unused record material, subject, as has too often been the case, to inadvertent destruction or casual loss.

With the transfer of the originals of theses to the Archives, a new problem has come to the surface. The Committee on Graduate School Policy (C.G.S.P.) sets standards for archival quality of the thesis original; the standards are sound, but the enforcement leaves much to be desired. It varies from department to department, and by the time the thesis arrives at the Archives, where it is checked, the student may have received his degree and left the Institute. We recommend as a solution that theses should be checked by the Archives for adherence to C.G.S.P. standards before being approved by the department.

Since space is now, and will be even more in the future, our key problem, we are doing our best to use what we have efficiently. One method is weeding, mentioned above in connection with Rotch. In a sense, moving blocks of older material to storage constitutes weeding; but the proponents of this solution usually have in mind a process whereby individual books are retained or thrown away on the basis of a decision as to whether they are ever likely to be used again. A number of studies have shown that the cost of this decision process, if it is to be made by qualified people, plus the cost of eliminating references to the book from all records, is higher than the cost of maintaining it on the shelf for many, many years. Add to this the fact that almost any book may be just what some historian needs some day, then the reluctance of librarians to do this item by item weeding becomes comprehensible.

There is another sort of weeding, however, with which we have experimented this year and which seems an obvious way of gaining shelf space. This is to discard multiple copies of books more than 10 or 15 years old. The cutoff date should probably vary according to the field. Experiments with the Science collections show that we can save up to 10 per cent of our stack space in some areas by eliminating all but one copy of books more than 15 years old. Judgment has to be used. More copies should be kept of books which have circulated recently and of classics. The gain here is a real one, and we plan to pursue this during the coming year. In the matter of record changing, we have decided not to indicate except on the shelf list that duplicates have been withdrawn. Moreover, for the moment we shall not attempt to eliminate multiple copies in different libraries.

Since substantial growth in the libraries is to be expected with each succeeding year, it is incumbent on the library staff to do careful planning, both short and long range. Most of the activities mentioned above have been in the short-range category. We have made long-range projections, however, for each of our libraries, and these are being checked each

year with performance. It turns out that every year until this one increases have been more rapid than anticipated. This year, because of budgetary stringency, we have been on target.

#### PHYSICAL CHANGES

In the Music Library, substantial progress has been made toward improvement. It is almost a classic case of how action can be forthcoming in answer to a concerted effort by students, faculty, and administration. I put students first because the move started with a group of music majors. They were unhappy with their library for a number of reasons: it was more of a lounge than a library; the lighting was dim; it was designed for listening to concerts of recorded music rather than for reading scores and books. Moreover, there was no room left for additional book materials or records, and the number of students in music continues to go up. A petition was signed by a majority of the students in the music section, asking that a committee of students, faculty, and library staff be set up to recommend improvements. This committee started to meet in November. Members of the Physical Plant planning staff were soon brought in. The needs were described, alternative plans drawn up, costs determined, money gathered from half a dozen different sources, and as the year ended new lights were being installed to be followed by a new rug, new furniture, additional stacks, and an improved layout.

A subcommittee studied the audio equipment, which has been in operation for five years and is beginning to be in bad shape. Moreover, it provides for too few students simultaneously. There are now only five listening rooms plus one seminar room. Even with the present number of students the subcommittee felt, and the whole committee agreed, that at least 15 individual listening positions with tape, disk, and earphones are necessary. The subcommittee worked out specifications which were sent out to a number of manufacturers, and bids were received just before the end of the year. We still have before us the problem of raising the money, but in the meantime refurbishing the rest of the room will proceed, with a completion date of September 15.

Almost at the same stage are the plans for remodeling the Humanities Library on the second floor of the Hayden Building, including a new ceiling, new lights, a rug and a paint job. These have been held up for some time, waiting first for a new roof which was put on last summer, second for extensive modifications of the air conditioning system overhead. Leaks in both have caused discomfort to staff, patrons, and books for a number of years. Dirt which had accumulated in the ducts after 20 years of operation with inadequate filters has been removed, improving air flow. It is to be hoped that the installation of improved filters will

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prevent further accumulation and output of dust into the reading rooms and stacks. The repairs to the air conditioning equipment are not yet completed as the year ends, and summer is hot upon us.

When the Humanities Library is completed, all our libraries will have been remodeled within 10 years; and all except Rotch will be air conditioned. Rotch badly needs air conditioning if only to maintain temperature and humidity at a level desirable for books. In that library more than any other we have a large number of valuable old folios and books whose paper and binding are deteriorating rapidly under present conditions. The comfort of the staff and patrons could also be helped, even by window units such as have been installed in many other portions of the main buildings.

At the end of the year we were at last able to carry out plans to divide the reading room on the ground floor of the north wing of the Hayden Building by installing a partition. The Reserve Book Room was compressed into the eastern half, leaving the western half for the Archives. The reading room section has been substantially upgraded with fresh paint, new stacks, and reupholstered furniture. The location of the Archives is especially desirable. Not only will it have ground floor space to exhibit important historical documents, but it is contiguous to an area which has been designated as the future home for our rare book collection. The latter is now in cramped, dirty basement quarters where the bottom shelves are below the level which the flood waters reached in the 1954 hurricane.

While the Institute has never had a policy of buying rare books, we have been the fortunate beneficiaries of a number of gifts containing rare and valuable material. For instance, there were many historic documents in the 1912 Vail gift of electrical and aeronautical engineering material. For years these have been on open shelves in the Engineering Library and some have been lost. This year we moved all pre-1910 items to the Rare Book Room. They will have value for the history of science and technology, a field in which our coverage is spotty. Not only do we lack funds for buying in this most expensive area, we also lack a clear sense of direction. We hope that the latter will be provided by the selection policy for Humanities.

Also located in the Rare Book Room is the unique H. H. Young Collection of historic American globes. During the year these were cataloged for the first time by Gerard L. Alexander, Chief, Map Division, the New York Public Library.

### STUDENT REPRESENTATION

In most of our planning the largest group using the libraries has been inadequately represented. They are students, both graduate and under-

graduate. A study made a few years ago showed that, while undergraduates form the highest percentage (46 per cent) of users, three-quarters of their work is class preparation and they require few books. Graduate students use the library in depth and form 35 per cent of the user population, faculty 12 per cent, others 7 per cent.

This year for the first time student representatives were invited to sit with the Executive Board of the Faculty Advisory Committee on the Libraries. The Graduate Student Council responded to the invitation and designated Richard W. Burrill from the Department of Economics. It is hoped that next year we shall be able to have at least one representative each of the graduate and undergraduate student bodies. Consideration should also be given to having representatives from other groups at the Institute, instructors, research staff, and others who use the libraries.

The fact that students have been inadequately represented in library planning is documented by studies mentioned at some length in my annual report of last year. These turned out to be of such general interest that they will be published in book form by The M.I.T. Press early next year under the title *Systematic Analysis of University Libraries: An Application of Cost-Benefit Analysis to the M.I.T. Libraries*, by J. A. Raffel and R. Shishko. The authors have also been in demand all year long by libraries and library groups to do consulting and give lectures.

The Raffel and Shishko studies show, among other things, that undergraduates would prefer shifting funds from research to reserve book facilities. Graduate students would not; they want more research materials and increased access to the collections of other libraries. We have not responded to these demands. The faculty ask for departmental libraries. We are planning to provide them for physics and chemistry.

What undergraduates want in the way of reserve book facilities is a second reserve book room like that in the Student Center but located near the east end of the campus. The construction of such a room would be most desirable, especially if the Department of City and Regional Planning moves to the east end of the campus, for it would allow the concentration in one place of the reserve book collections of urban studies, economics, management, and political science.

We really should not stop there. The community of interest among these fields is so strong that it would be far more efficient to bring these departments close together and combine their entire libraries. This would reduce duplication, thus releasing funds to be used for collecting in greater depth, and it would put all the books on the same topic on the same shelf so anyone using them could see our total resources without going from one library to another. Humanities should also be included, making possible the combined library described in my report for 1966-

67. Architecture and management could be included or not, depending on convenience to those served and efficiency — conflicting requirements which always have to be compromised. Convenience for students and for others working across a number of fields, as in urban studies, indicates centralization, so they don't have to trot from library to library. Operating efficiency would also indicate larger units.

#### SELECTION POLICIES

Some people think all we have to do is select books more carefully and libraries can be smaller. That is easier said than done. Quality is relative and time dependent. Selection on the basis of quality always has been and always will be difficult.

One of the areas which the ad hoc Committee on the Libraries selected for special effort was the development of selection policies for each of our libraries. A stated policy would help readers to know where to go to find particular classes of material and would help librarians avoid spending money on subjects covered in other libraries, saving it to build better collections of their own. Considerable progress has been made this year and we now have draft policies for each of the libraries except Humanities.

To return to the Dewey Library for a moment, it is there that it is most difficult to formulate a selection policy because the interests of the School of Management and the Departments of Economics and Political Science which it serves are so broad. They cover most of social science in different geographical areas, at different stages of development, from the most advanced societies to the most primitive. The present collection, consisting mainly of books and journals, is not enough to serve as a workshop for a research student. It cannot hope to answer the needs of a qualified scholar.

In order to get facts about actual present selection, a survey was made this year to determine which titles being bought fell outside the draft selection policies prepared by the librarians. The resulting figure was 6 per cent. More than half of these "out of scope" volumes were present in another library. It thus appears that 6 to 8 per cent of the book budget could be saved by adherence to the tentative selection policies. In addition, there are major areas of overlap which could be removed, leading to further savings.

We also have a draft of a general policy statement outlining principles to be followed in selection of various types of material, such as rare books, and assigning responsibility for continued development and implementation of the selection policies to the Director of Libraries, after approval by appropriate administrative committees. This draft has been approved by the Executive Board of the Faculty Advisory Committee on the Libraries.

As soon as the Humanities draft is ready the whole question will be brought up before the ad hoc Committee on the Libraries.

#### FINANCIAL CONTROL

Costs of libraries are going up 10 per cent a year; other costs, about 5 per cent. This means we have to have a bigger bite each year of total income. This cannot go on. More efficient operations and better financial control may be part of the answer.

Until this year we depended upon periodic reports of expenditures throughout the year to inform the librarians of the state of the funds at their disposal. Thanks to computerized operations in the accounting office, we have been able to get, this year for the first time, a complete month-by-month statement for each of our 300 order accounts — there is a separate account for each department or section of a department and these are subdivided again for books, serials and journals. This was an improvement; but keeping accounts on the basis of expenditures, without taking outstanding orders into account, has in the past resulted in the overexpenditure of individual accounts. Until this year no attempt has been made to set aside money at the time a book is ordered to cover the invoice when it arrives. At any given time there is a “float” ranging from \$70,000 to \$140,000 in outstanding orders. While this float seems to remain relatively constant for the library system as a whole, it fluctuates widely in individual accounts. This is caused by expensive individual items and by delays in delivery time running from a few days to several years.

We found from a survey that some accounts were regularly overexpended because orders continued to be placed until the day when the expenditures statement showed funds exhausted. By this time further outstanding orders sometimes amounted to several hundred or even thousand dollars.

Beginning in the middle of the year, we asked that each order include an estimated price. Rather than report expenditures to the librarians, we shall henceforth report balances unspent and uncommitted. When an invoice is received, the predicted cost will be corrected and the balance changed accordingly. The risk of overexpenditure is reduced to the sum of discrepancies between predicted and actual expenditures. This is an improvement but it brings with it a new problem. At the end of the year there will be in each account a “float” set aside to cover the cost of items which will be paid in later years. In the past unexpended funds have reverted to the general funds of the Institute. It has now been necessary to make arrangements for the float to be carried forward so that only the uncommitted balances will revert.

## LIBRARIES

One other area in the libraries in which better fiscal arrangements are needed is the Microreproduction Laboratory. A study has been under way this year to see how best to bring this about. The Laboratory is different from the rest of the Libraries in that it charges for most of the services it performs. Annual business is in the neighborhood of \$200,000.

The volume of copying services is about equally divided between members of the M.I.T. community and outsiders. Much of the internal work is for administrative offices. The payroll office is having computer printout filmed for easier use. The Engineering Library, INTREX, and the Medical Department are having extensive filming done also. Both microfiche and microfilm are in demand, with the former growing in popularity.

Consulting services are provided free by the Laboratory to a large number in the community, this year especially the Department of Physics laboratories. Moreover, every time a copy is purchased instead of the original being borrowed, the Laboratory relieves the libraries of the expense of processing an interlibrary loan. This is not inconsequential; 50 per cent of the theses borrowed from the Archives go to the Laboratory for microfilming in response to orders originating mostly outside the Institute. Incidentally, 85 per cent of the theses filmed are in engineering.

Prices have been too low to cover costs for the last two years, and volume has gone up from 1,100,000 prints to 1,180,000 this year. This deficit is increased by the cost of the free services provided. It would seem desirable that a regular budget appropriation should be made to cover services to the Institute community and that prices should cover the other costs, in order that there might be an incentive for the Laboratory to break even each year.

One area of deficit this year should correct itself next year. That is quick copying machines; the volume continues to go up on the eight machines in the libraries. We shifted this year from Xerox to less expensive SCM coin-operated machines where 5 cents per copy will cover the cost if the volume is sufficient. The break-even point should be reached next year provided recurring equipment breakdowns can be reduced. A program of daily preventive maintenance has helped. Unfortunately, no coin-operated copier is adequately engineered for the kind of load we impose on it.

## COMPUTER APPLICATIONS

Most of the applications of computers to libraries have been carried out so far with soft money, contracts, and grants; but the days of soft living are nearly over. Federal money and foundation money are tight. Not only are the odds that you will get a grant going down, but procedures for applying for government grants are increasing in complexity to the point where it may cost more to collect the required data, write

the proposal, keep the records, and submit the reports than you can hope to receive. Still, as we go into applications to our own libraries we can hardly expect anybody else to foot the bills. We shall have to pay them out of hard money, appropriated from general funds. At most we can hope for special appropriations to input a backlog or to write a program.

The computer revolution has hardly started. Libraries small and large have been experimenting for a number of years, and partial operating systems are springing up. Most of these are "dedicated systems"; that is, they are designed to fit the hardware rather than the reverse. The next phase should see the development of machine-independent software, which will have applications throughout the library.

#### INVENTORY CONTROL

The first area of computer application to libraries is, it seems to me, inventory control. Industry has proven it out. Publishers' warehouses have adopted it widely. While a library may seem superficially to resemble a publisher's warehouse, it is much more than that. Consider the amount of work that goes into preparing a book for retrieval. This accounts for 33 per cent of our total expenditures, not including the cost of books themselves, but only salaries, materials and supplies used in selection, purchasing, cataloging, card preparation, filing, and shelving.

We are now running an experimental project on control of purchasing by computer, starting with ordering and extending through catalog card production. The technical problems are harder than we thought, but still easier than the financing; for we shall have to run parallel systems for a year or so before we dare switch over. Of course, the more of our processes we can get computerized, the better chance we have of matching the costs of the manual system. Cost is the key. We will go to computers the minute they can do the same job for less money or a better job at a price we can afford.

The best guess now is that computer operation will cost 10 per cent more. This will have to be justified on the grounds (a) that we will have a machine readable by-product that can be used in operations such as circulation control and ultimately in a remote accessed catalog, and/or (b) that typists to do orders, lists, and catalog cards simply cannot be found — all year long we have had unfilled positions for typists in our Catalog Department, but we can get flexowriter operators. The latter argument may be the clincher.

#### STORAGE COSTS

In discussing computers, people rarely consider the cost of holding information in the memory. Shelf space is one of the cheapest things we have



today. Even amortizing land and building cost, we keep an average book on the shelf for a year for 20 cents. The contents of the same book on computer tape would require an annual outlay of \$74.70. The cost differential is a factor of almost 400. Consider the \$120,000 a year allocated in a program budget to keep the general and research collections on the shelves, multiply that by 400 and you find that it would cost \$48,000,000 a year to store our books on tape. Moreover, with present hardware, it would cost a lot more to find and output a book than to pay a professor's salary while he walks to the library, consults the catalog, finds the book, and borrows it. After all, a \$20,000-a-year professor only costs about \$12 per hour. All these figures prove is that nobody is going to put whole libraries on tape at today's prices.

It would be highly desirable to put the card catalog on-line, but again the costs are discouraging. The \$3,000 a year we now pay for space for the union catalog would come to \$6,000,000 a year were we to keep the contents in disk memory on the 7094. And that is still not the whole story. There is also the cost of input and output. As a first approximation, we may assume the cost of input into the manual and the computer system to be the same. Output costs change radically when you computerize. They are now borne almost entirely by the customer providing his own time. If a librarian makes a search for one item, the cost may be one dollar. On the other hand, a study at the University of Chicago came up with a cost of \$1000 for one pass through their catalog on tape. Output seems likely to remain expensive because catalog consultation cannot be batched unless response time remains on the order of minutes.

#### INFORMATION RETRIEVAL

In 1952 Louis Ridenour wrote in the *Scientific American*, "To describe its potentiality the computer needs a new name. Perhaps as good a name as any is 'information machine.'" It is fascinating but misleading to talk about information retrieval by computer as many people do today. As Max Woitschach of IBM Germany wrote in an unpublished paper, "There is really no identity between words or sentences and the actual information. This means that one and the same word or sentence may have a completely different meaning to different people." In other words, *information is not something we read out of a document but something that we read into it.* It is our interpretation in the light of our own prior experience.

Anybody who wants to spend a little time programming can do data retrieval. It doesn't matter what the datum is, whether it is a number, a word, or a paragraph, as long as it is formatted and tagged in such a way that you can retrieve it with a properly formatted and tagged query.

But no one today is doing information retrieval with a computer in the sense in which Woitschach is talking about it. Indeed, how can a computer do information retrieval if information exists only in the mind of the perceiver?

#### SOFTWARE

Aside from the cost of storage and processing, software quality is crucial to successful computer operation. After five years' work we now have a very capable family of computer-based tools for the handling of bibliographies, catalogs, inventories and text files in general. Functions available include organization, sorting, formatting, and archival storage as well as retrieval. It turns out that intelligent application of the subsystems is a more critical problem than originally anticipated. Disregard for minor details can add appreciably to the size of the human and machine effort. Costs can rise by a factor of two or more just because of a few seemingly trivial infractions of the rules of the road. The problem of subsystems matching and compatibility will have to receive considerably more attention in the future. Moreover, it is clear that library-related problems should not be solved in a parochial environment but must be seen in the large context of text and information management.

In 1967 the New York Public Library requested copies of our computer filing rules for serials and journals to study in connection with the conversion of their catalogs. Their rules, as printed in "Library Catalogs . . ." by Henderson and Rosenthal (M.I.T. Report No. 14, The M.I.T. Press, c. 1968), are the same as ours in technique and almost precisely the same in content. We are pleased that they have followed our approach rather than the complicated solutions frequently described in the literature.

There is some difference of opinion as to who should carry out the application of computers to libraries. A systems analyst will tell you that he, of course, has to lay the groundwork; then obviously you need expert programmers. This school of thought says, "Let the librarians tell us what they do now and what they want to do, then let us do it." Another school says, "There is no alternative to library experts learning computers." According to the second theory, librarians must learn to do systems analysis and programming in order to work out their own salvation.

At the Institute we take the compromise position that this is a joint problem which requires a joint task-force type of solution. We have systems analysts, programmers and librarians working together to get the job done. One of the results of this teamwork is an agreement that any bias of the file design will favour general retrieval capabilities rather than specialized card production. Our format will nevertheless be compatible with

## LIBRARIES

that of MARC in order that we may use their tapes if it becomes economically desirable.

To conclude this section, when thinking about the application of computers to libraries, we must keep clearly in mind what we know how to do and what we don't; what we can afford and what we can't. We know how to do inventory control; we know how to do data retrieval; but we don't know how to do information retrieval in any sophisticated sense. We can afford as much inventory control as can be handled within present budgets plus normal increases. We cannot afford on-line catalogs; and anybody who talks about storing any number of books in a computer, even off-line, is "off his head." There is a gap of two orders of magnitude between "the computerized library" and what we can afford.

In order not to end this section on too pessimistic a note, I close with a quotation from the Annual Report for 1968 of Fred C. Cole, President of the Council on Library Resources:

In sum, the technology is expensive and uncertain, both the research and development and the equipment. Nevertheless, library problems will worsen and the remedies grow more costly if the subject of automation is neglected today.

## GIFTS

We have had many gifts this year from friends at the Institute and outside. One particularly significant donation was a collection of 2,400 volumes of books, journals, and technical reports from Lawrence Levy, president of Allied Research Associates, Inc. These are current materials in a number of scientific fields. They are in superb condition and will be put to immediate use. It is a pleasure to express here the gratitude of the Libraries to Mr. Levy and to the many other generous friends who have made us gifts this year.

## STAFF ACTIVITIES

The libraries have an energetic, enthusiastic staff. It is unfortunately impossible to mention the contributions and activities of all; but I do want to express my appreciation to the department heads whose work and whose reports have furnished the raw material for this report, also to those many staff members who have worked long and well on committees, one on Loan Procedures, Mrs. Reay Frève, Chairman; another on Borrowing Privileges, Mrs. Ching-Chih Chen, Chairman; and a third on Staff Classification and Descriptions, Mrs. Frances L. Needleman, Chairman.

## CONCLUSION

This has been a good year in the sense that we have coped with the immediate problems and have done short-range planning. Comprehensive long-range planning is impossible because of large, unresolved questions of Institute policy.

WILLIAM N. LOCKE

**THE M.I.T. PRESS****HIGHLIGHTS**

The M.I.T. Press from July 1, 1968, to June 30, 1969, published 111 and produced 125 new books, bringing the number of books published to a total of 739 since the Press was founded in 1933. Sales of books and journals published by the Press last year were \$1,904,869, up 18 per cent from the previous year. This places The M.I.T. Press after the university presses of Oxford, Cambridge, Harvard, Chicago, and California in rate of publication, and behind the same presses but equal to the presses of Princeton and Yale in sales. We are unlikely to change these rank orders significantly, but we remain among the largest and best of our kind. This year's increase in sales was entirely the product of publishing more new titles than last, and *that* contrast, explained last year, was the result of past editorial, design, and production delays in transforming a manuscript to a book, rather than increased vigor in editorial procurement this year. We are budgeting next year for a 10 per cent increase in titles which will, because of the salutary sales prospects for certain forthcoming titles, produce an increase in sales of at least another 18 per cent, and it may run as high as 30 per cent if one large, expensive, good book, *The Bauhaus*, sells well. The message is clear: The Press is managing to find more titles that meet M.I.T.'s editorial standards for publication, and is distributing them more widely and, as we shall see, more efficiently.

This past year the most notable award to our authors came in the form of the American Historical Society's award of the \$5,000 Albert Beveridge Award to Michael Paul Rogin for his *The Intellectuals and McCarthy: The Radical Specter*. The most notable recognition given the Press for its design activities consisted of the American Institute of Graphic Arts and Association of American University Press selections of three Press publications, Paul Frankl's *Principles of Architectural History*, Herbert Simon's Karl Compton Lectures, *The Sciences of the Artificial*, and M.I.T. diving coach Charles Batterman's *The Techniques of Springboard Diving*, as outstanding instances of good book design and production.

Our journals department, which began formal activity this past year, now publishes the *Journal of Applied Mathematics* and will distribute the *Mathematical Biophysics Journal*. It is initiating two new Press-owned journals: *Linguistic Inquiry*, to be edited by S. Jay Keyser, and a journal of interdisciplinary history, to be edited by Robert I. Rotberg and Theodore Raab. The Press also will distribute a new publication of the Music Critics Association of America, *The American Musical Digest*.

Table I Publications and Sales

	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70 (est.)
New Hard-Cover Books	18	43	49	57	65	54	83	95
Paperbacks	0	10	17	20	20	20	32	24
Imports	0	5	12	9	15	2	10	15
Total New Books	18	58	78	86	100	76	125	134
Sales (\$1,000s)	\$ 301	487	1,027	1,210	1,633	1,608	1,905	2,250
Net Operating Margin	(\$18,600)	(40,500)	61,600	17,900	(29,000)	40,100	173,675	36,700 (est.)

Plans for renovating, at Press expense, the M.I.T.-owned building at 28 Carleton Street are being completed by F. A. Stahl and Associates, working in collaboration with the M.I.T. Planning Office and Buildings and Grounds. Occupancy of the first floor is scheduled for January 1, 1970, and the second and third floors should be ready by summer of 1970. It is hard to overstate the prospective benefits of essential space for major Press activities, notably those concerned with manuscript preparation.

#### DEPARTMENT SUMMARIES

##### OFFICE OF THE DIRECTOR

Now in its seventh year under present management, the director's office consists of the director, dividing his time between editorial procurement and administration; a secretary; and a legal assistant handling all contracts, rights, copyrights, and permissions. This year Constance D. Boyd, formerly executive editor, was appointed assistant to the director for editorial concerns, to see that manuscripts were truly ready for release to editing before doing so. Her talents are widely known and acknowledged throughout the M.I.T. community, and we think we are now making the most effective use of them.

The M.I.T. Press Board met eight times last year, reviewing 163 publication proposals and accepting 127, as compared with 172 proposed and 138 accepted the previous year. The Board exists to govern the use of M.I.T.'s imprimatur on published works. It meets to review the Press's own procedures and to sustain or reject the Press's judgment of the substance and quality of a work proposed for publication. Acceptance of 80 per cent of the books proposed indicates that the Press is following selection procedures essentially in accord with principles of scholarly evaluation by Institute faculty. The rejection of one book proposal in five means that either the Press is stretching the Board's range of credulity or that we have done our homework less than adequately. In any event, it indicates that the Board is far from a "rubber stamp."

It seems insufficient merely to acknowledge our deep gratitude to three retiring members of The M.I.T. Press Board, since these three, Paul R. Gross, Morris Halle, and George B. Thomas, Jr., brought remarkable scholarly breadth and publishing understanding to their task. Each served substantially. We must credit Morris Halle with the lasting legacy of the linguistic monograph sequence which he created.

##### EDITORIAL ACQUISITIONS

As in past years, all book procurement for the Press was done by Michael J. Connolly, editor-in-chief, and the director, roughly dividing their fields

of activity. The past year the editor-in-chief assumed responsibility for the humanities, social sciences, and sciences, while the director supervised editorial acquisition for engineering, management, architecture and planning, and the Centers for International and Urban Studies. This was a loose division of labor, but it established an important principle of accountability. During the year Barbara K. Levey was promoted to coordinating editor, and, recognizing both the need for greater coverage and an available talent, John S. Snyder, Jr., one of our salesmen, was appointed assistant editor with specific responsibilities for editorial procurement in the engineering area.

The number of proposals and manuscripts reviewed by the Press each year is a function of the reputation of the Press, recent successful publications, and of deliberate procurement. It follows that we have reviewed 20 per cent more proposals and projects this year than last, 474 against 397, and that we shall review substantially more next year. The yield is relatively high because most of our projects are known from their inception and encouraged until they have grown to a scale for fair review. Last year we offered or signed contracts for 148 books, compared with 125 the previous year, with subject distribution as follows:

	Social Science	Humanities	Engineering	Science and Mathematics	Art and Architecture
1967-68	42	39	15	29	Included in Humanities
1968-69	45	30	22	35	16

The figures for contracts by subject matter indicate that the list is better balanced this year than last. Engineering and science and mathematics contracts are 30 per cent higher than last year; social science is about the same; art and architecture, at 12 per cent of the total, are approaching a desirable level.

Of our more than 700 publications, 88 have been translated into at least one foreign language. We have signed, overall, 176 translation agreements. Last year, we signed another 28 agreements, and we have 195 options for translations presently outstanding.

#### EDITORIAL PREPARATION OF MANUSCRIPTS FOR PUBLICATION

The editorial care and concern we give to manuscripts has been and still is the strongest reason for an author to publish with this Press. We have a capable and experienced cadre of senior editors. Succeeding Constance D. Boyd as executive editor this year was Ruth W. Gillies, a former senior

editor with seven years' experience with the Press and previous service in commercial publishing. We acknowledged Joseph Stein's language skills by designating him translations editor and placing under his responsibility all translations, translation contracting, and the editing of all translations. Harold F. Chevalier continued as production director, with responsibility for overseeing both editorial preparation and production.

Two changes of procedure are worth noting for the record. The first is the thorough review of a manuscript by Constance D. Boyd within the editorial procurement area before a work is released into manuscript editing. The second, mentioned last year, is the practice of editorial work for the Press on a free-lance or contract basis. Altogether our staff and 25 free-lance editors edited 28,869 pages of manuscript at a cost per page of \$4.35, up sharply from \$3.38 last year, but still a substantial contribution to the rectitude and clarity of text in publications bearing the imprint of M.I.T.

The Press, working in a community rich with editorial skills and talent, actual or potential, has in the past been staffed to handle its lowest continuous editing work load. Then free-lance editorial assistance has been called in for those peak periods such as the end of summer or early February when many manuscripts are delivered and rushed into editing. As physical space for the Press remained constant and more manuscript editing was needed, our proportion of free-lance editing grew. In three years, the balance has shifted from two-thirds in-house editing to two-thirds free-lance editing. When the work was evenly divided in-house and free-lance last year, it was thought a good idea to ask each of four senior editors to supervise new free-lancers, rather than have a single contractor and supervisor do so. It seems open to question now whether this was wise. We have a highly skilled group of senior editors who are spending virtually full time supervising the work of new or inexperienced free-lance editors. Unlike in-house editors, free-lance editors, once trained, go off on other assignments, and we may quickly lose the value of our investment in their training. Moreover, we are only now cost accounting the training with the direct contract cost of such free-lance editing. The policy question is whether our fraction of free-lance editing, even by our more experienced free-lance editors, should ever be larger than our in-house editing. The management question is, how do we most efficiently manage this large contract service activity?

#### DESIGN

Our original plan, to give everything visible about M.I.T. Press publications and activities a consistent and contemporary image, is still in force but not much more fully implemented this year than last. Nearly two-fifths



of the design department's effort this year was devoted to a single very large publication, *The Bauhaus*. Whether this expenditure was justified, time will tell, but we believed it deserving of the commitment. The remaining time was devoted to the exteriors of our books and office activities: jackets, exhibits, direct mail promotions, advertisements, posters, and labels. The interiors of only a dozen or so of our books were fully designed by the design department and another dozen fulfilled standards of its creation. Half the balance were designed by members of the production department, and the others were given us in camera-ready form.

Next year should see us much closer to our goal of providing standard designs for all series and sequences, full design of all books where layout is important, and for the rest, adaptation from successful models, previously devised. It is imperative that the design department's standards of visual design, now applied to a fraction of the Press publications, be extended to all Press products. The department is now fully staffed by its director, Muriel R. Cooper and Lauri E. Rosser, who has now been promoted to assistant designer, and a design apprentice.

#### PRODUCTION

No Press department performed last year more effectively than the production department. Young, hard-working, and quick to learn, they forgot they were new to their jobs and gave high measures of performance to their department. Dwight E. Agner, in his first year as Promotion Manager assisted by Mrs. Sylvia Steiner, appointed Assistant Production Manager in the first quarter of last year, handled the estimating, contracting, and traffic of obtaining 21,453 pages of new composition to and from their suppliers, a quantity increased heroically from last year's more leisurely times, and a third over our previous high of two years ago. In addition to fulfilling one of our aims of last year, we were able to secure 5,818 pages of new text in camera-ready form, a gain from 3,696 pages last year, meaning that it had been edited, designed, and composed by others before coming to us for photo-offset production and binding. Since the total number of pages edited this year was roughly the same as last, the production burden for next year ought to remain constant too. Until the design department can accomplish its mission fully, production will be obliged to contribute to Press book design, but on a declining curve.

#### SALES AND PROMOTION

The truest measure of the effectiveness of a marketing activity is the dollar return on marketing dollar investment. The increased efficiency of this function over time is pleasingly revealed by these figures:

VICE PRESIDENT, RESEARCH ADMINISTRATION

	1966-67	1967-68	1968-69
Total Marketing			
Expenditure	\$ 341,733.00	\$ 320,000.00	\$ 315,000.00
Sales Volume Achieved	1,633,312.00	1,610,000.00	1,904,000.00
Volume per Sales and Promotion Dollar Spent	4.74	5.03	6.04

The major activities are worth noting in some detail. This Press has always relied heavily on direct mail, but it has only been recently that we came to regard our catalogue, heretofore prepared for bookstores and a few others, as our strongest single direct-sales instrument. Arranging our catalogue so as to facilitate subject catalogues for multiple mailings, we have increased our mailings from an average of 500,000 pieces per year to 1,700,000 pieces this year, while reducing our cost per average thousand pieces mailed by two-thirds.

Next to direct mail, our largest marketing investment is in our field sales effort. We continue to sell our books domestically through our standing-order plan, which permits qualifying bookstores to order not by title but by subject area; our agency plan, which encourages bookstores to stock more of our titles for additional discount; and by plain hard work: sales visitation with computer reports in hand to show the stores the number of special orders and the advantage of the agency plan. The salesmen then make a laborious check of physical stock of our titles throughout the store, returning the unsold or unsalable books, working up a suggested order for the store buyer to confirm. Last year our three domestic salesmen called on 651 bookstores in 33 states once each, and on 425 stores two or more times. We have continued to refine our agency and standing-order plans to reduce returns, and now serve 179 agencies in this country.

Other promotion and sales activities have been commented upon before in detail. Our generous review copy distribution continues, but we need to try to measure its effectiveness. We need to experiment more with free paperback distribution to college and high school teachers who might be potential users. We continue to do news releases on books where the publicity will help the author, the book, or our sales. Our exhibits program is in transition from shared exhibits to a substantial number of our own. New equipment helps. It has already gained us an award from the American Library Association (A.L.A.) for the outstanding single booth exhibit at the 1969 A.L.A. Conference.

As stated in last year's report, we combined with the University of Chicago Press in a joint venture in London to sell our books throughout the United Kingdom, continental Europe, and the British Commonwealth and the world markets traditionally served therefrom. The London ven-

ture has worked well, particularly in England, and performance should improve as we bring up reinforcements in the form of mail promotion there and on the Continent. We handle the Far East, India, and Central and South America from Cambridge.

Our major overseas customers continue to be the British, the Japanese, the Germans, the Italians, and the French, in that order. We are proud of our foreign sales, which are slowly declining as a percentage of total sales but continue to increase in volume in spite of some difficult areas. In the next year, Canada should show decided improvement as we begin to sell directly there, and our Australian representation will be extended to Indonesia and Malaysia. We are in trouble in an American university-press cooperative in Mexico, and throughout Latin America currency problems and low library budgets afflict us. India is not yet a major market for our books.

The time is approaching when we must experiment with lower sales prices in selected foreign markets. A graduate student at an Indian university cannot pay what one here at M.I.T. may. Most of our books will not reward an Indian publisher were he to produce it in a low-priced edition. Therefore, we must take selected titles, view the total world market as a composite of many distinct markets, and resolve to sell at appropriate and different prices in each. Selected text publishers have successfully applied this formula, and we must venture it at least experimentally.

Rebecca M. McGovern as sales and promotion manager, Randall C. Goff as assistant promotion manager, and W. Joseph Chaput, as sales manager, have carried us to a very good sales year, and next year with more salable titles ought to be even better.

#### BUSINESS

As I have not detailed the functions of the business department in any previous annual report, I do so now. Functionally sequenced, orders come to our mail room, both direct from the Kendall Square Post Office and through the Institute mail. Mail is sorted in our mail room, and orders separated, opened, coded, and a punched tape created for computer production of invoices and data distributions. Payments are separated, routed first to a cashier, then to the credit department. John L. Pelletier, credit manager, and his assistant manager, Mrs. Laura Senn, try to keep our payments reasonably current; nonetheless, an increase of 18 per cent in sales this year brought a 45 per cent increase in our accounts receivable. In an industry that is notoriously short of capital, constant credit vigilance is required. In certain quarters of the Institute our accounting department once had a renown which we are keen to forget. That these days are past is the work of a wholly new accounting staff, which, under Cornelius F.

Kiely as manager, is responsible for producing quarterly financial statements, annual royalties statements, monthly inventory records, and processing all our payables. This has been done well and accurately this past year. For next year, we intend to broaden the scope of accounting to include all statistical requirements of the Press, most particularly those pertinent to management. Edward W. Haas and his assistant, Mrs. Barbara J. Saulenas, guide, instruct, supervise, and pinch hit, as managers must in businesses our size.

Business office expense as a percentage of net billed sales has declined steadily since 1966, from a high of 14.4 per cent to an estimated 8 per cent for last year. Part of this improvement has come from fewer but larger orders, the average invoice climbing from \$16.85 in 1966 to \$23.50 last year. Still, there is improvement to be made, in more error-free order fulfillment, in more careful coding and computer input, and in reducing the need for adjustments and credit memos. But this is a sound department with good experience, the kind to carry us through as heavy a year as 1969-70 promises to be.

#### SHIPPING AND WAREHOUSING

The Press has maintained a workable warehousing agreement with Technical Impex, Inc., of Lawrence, Massachusetts, over the years. This firm, which also provides us with computer services, has served us well enough, especially during the past two years. But the industry-wide differential between contract and publishers' own warehousing is roughly 2 per cent, and 2 per cent is significant. Therefore, we are undertaking a study this year of handling our own warehousing, by ourselves, or in conjunction with other presses. It seems likely that it will prove essential to bring our warehousing under our own control by the end of 1970, as predicted in the ten-year forecast.

#### CONCLUSION

Following these operating summaries, let me say that approximately half a million books bearing the name of M.I.T. were bought by someone, most of them by libraries and individuals, all over the world. Of our 700 in-print titles, only 106 sold more than a thousand copies this year, and of those, 76 were paperbacks. Only nine titles, including one hard-cover book, R.G.H. Siu, *The Man of Many Qualities: A Legacy of the I Ching*, sold more than 5,000 copies, and only two paperbacks more than 10,000. University publishing remains essentially a business in which one sells a single book at a time in a specialized field to a professional or academic buyer at a price he often finds hard to pay.

In summary, 1968-69 was a good year. Now for the vintage year coming up.

CARROLL G. BOWEN

**OPERATIONS RESEARCH CENTER**

The staff of the Center, being at the same time members of six different departments in three schools, are responsible for teaching most of the subjects related to operations research. Thus, although a graduate student at the Institute may have to choose subjects from different departments and schools, he can obtain a complete grounding in this field.

An increasing proportion of research, both by faculty and students, has been in the general area of public systems. The thesis on blood banking under the supervision of Professor Alvin W. Drake, mentioned last year, is nearing completion; several of the conclusions are already being implemented by the Massachusetts Red Cross Blood Center. Further study was begun on the problems connected with the introduction of computers into the blood supply system. Professor Thomas B. Sheridan is cooperating with the M.I.T. Instrumentation Laboratory and the Massachusetts General Hospital on the problems of medical telediagnosis — a dynamic programming scheduling of the doctor's attention over telediagnostic channels vis-à-vis his physically traveling from one place to another to render his attention in person. Theses on scheduling of ambulance services and the allocation of police patrols are examples of specialized urban transport problems under study. Another doctoral thesis, under Professor Jerome Rothenberg, involves a study of the municipal budgetary process, in cooperation with the city government of Worcester, Massachusetts. Investigations of problems in education and housing are also under way. Forecasting of educational needs is the subject of a thesis research under the direction of Professor Leon S. White. Professor White is also working on management problems in higher education, with special applications to the Institute. Another thesis, developing a model for the prediction of demand and supply for housing, is being supervised by Professor Rothenberg.

Work also is expanding in the general area of transport, both directly in the Operations Research Center and also in cooperation with Project TRANSPORT and work in other departments. Professor Ernst G. Frankel and his students are continuing work in the development of techniques for the planning and control of ship production, operation, and loading. Part of the work done this year concentrated on the problems of the Port of Boston. A number of theses under Professor Robert W. Simpson were devoted to study of various aspects of air transport: scheduling, routing, and computerization of management. Work under Dr. E. Farnsworth Bisbee has continued on rail transport scheduling in connection with the systems proposed by Project TRANSPORT. A study of truck scheduling was also carried out under Professor John F. Pierce in collaboration with a large trucking firm.

The theoretical techniques of mathematical programming for the study of stochastic systems is continuing under the direction of Professors Drake, Gordon M. Kaufman, John D. C. Little, and Jeremy F. Shapiro. Practical applications of some of this work have been made to equipment faults in automatic telephone networks, scheduling of multiple warehouses and factories, multi-elevator operations, and traffic circulation networks within large buildings, to name a few examples. The techniques of market survey and prediction have been used by Professor Little in analyzing the management information system for a political campaign. Many aspects of basic theory have been the subject of other theses on decision theory, dynamic programming, and Markov processes.

The Special Summer Program, Operations Research for Public Systems, will be presented again, in early September, 1969. More than half the speakers this time will be drawn from M.I.T. faculty and students.

Visitors during the year have included Havard Hegna, on leave from the Norwegian Computing Center; his work has emphasized simulation studies of computer operating systems. Visiting the Center last summer to work with Professor Donald C. Carroll were Dr. Peter Mertens, vice president of Orga-Ratio AG, from Starnberger See, and Heinz Kress of the Technische Hochschule in Munich, both here under the auspices of the Deutscher Akademischer Austauschdienst.

Professor Philip M. Morse retires as director of the Center at the end of this academic year. The new director will be Professor Little. Professor Drake continues as associate director.

Details of the Center's activities, outlined above, are given in the Center's Annual Report for the year 1968-69.

PHILIP M. MORSE

ALVIN W. DRAKE

## SUMMER SESSION

The 1968 Summer Session represented a continuation of the past trend toward more activity at M.I.T. in the summer — more Special Summer Programs, more regular students, and a variety of conferences.

### SPECIAL PROGRAMS

The one- and two-week Special Summer Programs provide an opportunity for professional men and women to study new developments in their fields. There was a registration of 1,842 people in 39 programs as compared with a 1967 registration of 1,829 in 38 programs.

There were two distinct shifts in the composition of the registrant body. Budget restrictions, at the national level, resulted in a decrease in the

number of registrants from governmental agencies. Men and women from these agencies accounted for only 21 per cent of the registrants, as compared with a normal representation of 30 per cent. Also, faculty from other institutions accounted for 15 per cent of the registrants in 1968 as compared with 21 per cent in 1967. This decrease can be attributed to the termination of the Ford Grant for engineering faculty.

During the year, we conducted a substantive analysis of the desires of registrants who attend Special Programs. The results of the study and the conclusions have been summarized and have been made available to faculty who propose programs. A most significant aspect of the study was the outside response to a three-page questionnaire which was mailed in December. More than 80 per cent of the registrants in the 1967 summer series returned completed questionnaires. This response, together with the many thoughtful comments, demonstrated that we have a strongly motivated group of registrants attending the Special Summer Programs.

#### CONFERENCES

One hundred and fifty people attended some sessions of the Summer Institute in Dynamical Astronomy, which ran June 17 through July 13, with financial support coming from the National Aeronautics Space Administration (NASA) and the National Science Foundation. Professor Robert G. Stern of M.I.T. was co-host with the Smithsonian Astrophysical Observatory at Harvard and NASA.

The Institute was host from June 20 through 21 to the Sixth Annual Computer Personnel Research Conference, attended by approximately one hundred people. David B. Mayer was vice-chairman of this group, which met under the auspices of the Association for Computing Machinery.

The Urban Systems Laboratory conducted a summer study, "Urban Information Systems," at M.I.T. intermittently from June 24 to August 23 for 18 people, and another session from June 27 to August 23, "Management of Urban Solid Wastes."

Elmer C. Bartels of the Division of Sponsored Research made arrangements for a very interesting event, the Bay State Wheel Chair Games, which were held at M.I.T. June 28 to 30. One hundred and ten participated.

The Sixth International Symposium on Rarefied Gas Dynamics was held at the Institute July 22 to 26, under the direction of Professors Leon Trilling and Harold Y. Wachman. There were 378 registrants, and some members of their families.

Robert A. Schuiteman, associate foreign student advisor, was in charge of arrangements for the BASIS program. This was arranged for foreign

students who had been admitted to educational institutions in this area and in other parts of the country, and was partially funded by grants from the Institute of International Education and the Ford Foundation. Its purpose was to provide the participants with information relative to their universities' fields of study, to improve their English language proficiency, and to provide a variety of social, cultural, and recreational activities. Forty students attended the six-week program from August 3 to September 13, and 46 attended the three-week program from August 24 to September 13.

Professor David N. Hume made arrangements for a meeting on August 15 and 16 of the 12 members of the Thermal Analysis Standards Committee of the International Conference on Thermal Analysis.

Housing and facilities were provided for a summer seminar for Teachers of Motor-Deprived People, under the sponsorship of the Sensory Aids Evaluation and Development Center, with Teachers' College, Department of Special Education, Columbia University, participating. Twenty-two attended this seminar from August 19 to 20.

The Department of Civil Engineering was host to the Hydraulics Division, American Society of Civil Engineers (A.S.C.E.), in conjunction with the Boston Society of Civil Engineers and the Massachusetts Section of the A.S.C.E. Four hundred and twenty engineers and six hundred in all attended the conference, which ran from August 21 to 23.

Some four hundred members and students registered for the A.S.C.E. Specialty Conference on Placement and Improvement of Soil to Support Structures. Professor Charles C. Ladd was in charge of arrangements for the three-day meeting from August 26 to 28.

Once again, the A.I.E.S.E.C. (International Association of Business and Economic Students) held a meeting at the Institute. Approximately 175 businessmen, professors, and deans of schools of business and economics, representatives of international organizations, institutions, and foundations, as well as outstanding students, participated. The title for the conference, which ran September 4 to 6, was International Transfer of Management Skills.

For the tenth consecutive year, M.I.T. students conducted a Summer High School Studies Program for talented students. Under the direction of Charles F. Manski '70, 35 college-level courses were taught by undergraduate and graduate students from M.I.T. and surrounding colleges. This was a significant increase over the 1967 total of 22 courses. More than seven hundred students attended classes two nights a week, for eight weeks. The subjects were varied. Among the more popular courses were those in science, mathematics, drama, Negro history, philosophy, and cosmology. This voluntary activity on the part of the instructors has



**SUMMER SESSION**

become so popular that it is continued on Saturdays during the regular school year.

**REGULAR SUBJECTS**

The number of subjects has remained substantially constant during the past five years. Registration figures are as follows:

1964	1965	1966	1967	1968
1,882	2,090	2,067	2,218	2,490

The increased enrollment since 1964 can be attributed to the expanding size of the Graduate School. Graduate students (2,104) represent 85 per cent of the student body during the summer term.

**JAMES M. AUSTIN**



## VICE PRESIDENT, SPECIAL LABORATORIES

**T**he “sharp and searching debate,” referred to in last year’s report, as to the proper role and responsibility of the University in relation to national problems and programs has become even sharper and more vocal. Like other campuses around the country, M.I.T. has experienced campus dissent.

The focus of much of the dissent in the past year has been on the nature and size of the defense programs at the Special Laboratories. Particular programs at the Laboratories were chosen for special criticism and were held up as examples of unfortunate Institute commitments. Some of the important and fundamental issues raised were clouded by misinformation and misunderstanding.

The Poseidon Guidance Program at the Instrumentation Laboratory was one most widely and severely questioned. In 1966, the Navy contracted with the Instrumentation Laboratory for a program to design and develop the guidance system for the Poseidon missile — a missile designed to carry Multiple Independent Re-entry Vehicles (MIRV). The need for MIRV for our national security and its possible escalating effect on the nuclear arms race have been a matter of great concern to the public, the Congress, and the press. The public debate on the consequences of MIRV deployment led naturally to concern on campus about the propriety of the Instrumentation Laboratory’s program for the development of the Poseidon guidance system.

Many people, in their understandable frustration about the continuance of the Vietnam War and the inadequate attention to the solution of social problems, desire that the Institute use its leverage to attempt to change and to improve the direction of national effort. In an attempt

to cope with the complex issues raised and with the basic matter of the relationship of the Institute to the Laboratories, President Johnson appointed a review panel chaired by Dean William F. Pounds and including members from faculty, student body, Laboratory staff, administration, Corporation, and alumni. In his letter to the M.I.T. community announcing the panel, he stated:

The function of the panel will be to evaluate the implications that the laboratories have for the Institute in its prime responsibility for education and research and in its responsibility for service to the nation. I would ask the panel to review the appropriateness for Institute sponsorship of the current programs at the Laboratories, the decision-making process by which new programs are accepted, the relationship of the Laboratories to on-campus research and education, and in general, the longstanding policies and procedures with respect to public service obligations.

On May 31, the panel submitted a first report based on weeks of intensive hearings and deliberations. Witnesses were invited by the panel and, also, individuals requested the opportunity to testify. The panel submits its final report in October, 1969.

The first report recommended that:

1. The Laboratories and M.I.T. should energetically explore new projects to provide a more balanced research program.
2. The educational interactions between the Special Laboratories and the campus should be expanded.
3. There should be intensive efforts to reduce classification and clearance barriers in the Special Laboratories.
4. A standing committee on the Special Laboratories should be established.

In addition, the review panel concluded "that the Poseidon program at this stage of its development is inappropriate for M.I.T. sponsorship" and added that:

5. The M.I.T. administration review the Institute's future commitments to this program. It recognizes, however, that M.I.T. must be prepared to honor its existing contractual obligations.

The preliminary report was well received by the Institute community, as well as by the government and the public. A widely held reaction to the report was expressed in a *New York Times* editorial on June 4 entitled, "Sense on Defense Science," which read as follows:

An important part of the current revolt on American campuses is directed against the dependence of universities on research contracts from the armed forces. Many students and professors complain that science is being chained to a military chariot when the most urgent tasks for scientists lie in making the cities more livable and enhancing the quality of life.

No center of learning has had to face more searching inner questioning on this

issue than the Massachusetts Institute of Technology, which operates two special laboratories heavily involved in secret projects for the Defense Department and the space program.

The report on these laboratories just issued by a panel representing all viewpoints from M.I.T. trustees to "New Left" undergraduates is a significant contribution to sanity and social responsibility, not merely for M.I.T. but for all scientists, on questions that have caused deep concern to the entire academic community since the dropping of the first atomic bomb on Hiroshima a quarter-century ago.

The report is admirable as evidence that confrontation tactics have not yet entirely elbowed rationality out of formation of university policy. It is equally admirable as reassurance that the restructuring of universities to allow a more effective voice for students and faculty can bring beneficial results for the institution, when all elements proceed with a genuine desire to arrive at consensus instead of polarization.

Specifically, the panel calls for a gradual shift in priorities at the two special laboratories to provide a better balance between military and civilian projects. But even the most radical members of the panel acknowledge that it would be self-defeating for M.I.T. to sever its ties to the laboratories or to ban all classified defense work on campuses.

The sole effect of such a spinoff, in the absence of a basic redirection of Government research activities, would be to force the armed services to set up more laboratory complexes of their own or to give huge new contracts to aerospace and other corporations. The result would be precisely opposite to the one desired by the student and faculty dissenters—a strengthening of the military-industrial complex and a diminution in the capacity of university scientists to exert any useful influence in the shaping of public policy on military matters.

The administration plans to give its attention to implementing the results of the panel's study as promptly and effectively as possible although we face many difficulties in doing so.

Last year's report stated that "transportation, medical care, and environmental control problems are getting increasing attention nationally, and staff members of both laboratories are enthusiastic about finding ways to apply their experience to these areas. It is expected that such involvements will continue to remain relatively modest in the foreseeable future. However, if the nation's commitment to solving such problems matches its increasing concern about them, M.I.T.'s laboratories have the dynamism to adapt their unique talents to research in these areas."

However, as this report is written, there is little reason for optimism about a national commitment which implies substantial funding in the immediate future for new technological efforts in solving social and domestic problems. Defense and space technology have until now been sufficiently well funded to utilize the talents of large, technological laboratories. Assuming the greatest will in the world to change directions (and there can be legitimate debate about even the desirability of major changes), nothing substantial can happen without adequate financial support. Even in those areas where funds are now available or potentially available, much time and effort will have to be devoted by administrative

and technical staff, meeting with government people to mesh interests and abilities with funding allocations.

There will continue to be debate — hopefully it will be in a style and spirit which permits difference of opinion and philosophy to be discussed. Some basic questions, perhaps insoluble, will have to be weighed in evaluating future directions.

1. What is defense or “war-related” research? Is any program financed by the Department of Defense or the Atomic Energy Commission in this category? Is all research which may contribute to a better understanding of weapons technology “war-related” research? In the past year, for example, some of the most effective testimony against increased armaments came from experts intimately related to weapons technology.
2. Is there any appropriate role for a university in defense research? How remote from actual production and deployment does such research have to be? Should the Special Laboratories see an important national service in providing an objective perspective to the Defense Department? Can other sectors of the technological community provide this “neutrality” as effectively? If we believe that deterrence is in fact fundamental in preventing a nuclear war, can we then see a proper role in strategic weapons research? Perhaps the greatest potential danger to mankind will come from areas of research other than weapons technology (microbiology, for example). How may we cope with that possibility?
3. What is the time scale in which we are able to confront these problems? This will depend on the nature of dissent on the campus. Are we willing to terminate contractual obligations very quickly to meet new standards, even while we recognize the havoc this move will create both within the Laboratories and in our relationship with the government?
4. The more than 3,000 people employed at the Laboratories are doing an outstanding job. What is our obligation to them in handling the problems of transition? Certainly the Institute community wants the Institute to be a responsible employer. How do we handle problems of morale, redirection of effort, and so on?
5. How do we handle the impact of major Laboratory changes on the financial organization of the Institute?
6. Is there conviction in the Institute and in the national technological community that the Special Laboratories are indeed almost unique technological Laboratories that the country cannot dispense with? A good technological organization is years evolving; are we in danger of throwing out the baby with the bath?
7. Can the Institute evolve a “rationale for all seasons” which clarifies its public service role? Is it all right, for example, to work on transportation

## INSTRUMENTATION LABORATORY

when the result might be a controversial highway program? Can there be any consensus on what constitutes desirable and undesirable research?

These are some of the fundamental issues which will determine the future of the Laboratories. Though this report is in some ways pessimistic, the Pounds panel has certainly opened the possibilities of increased understanding and communication between Laboratory staff, faculty, students, and Corporation members. If questions can be raised and handled in an open and orderly way, M.I.T. can perhaps provide leadership in demonstrating the importance and the possibility of converting technology to important domestic and social needs. The year ahead will not be an easy one, as we come to grips with these problems. We hope that it will be possible for people to work constructively and patiently toward the important goals which we have set. Change will no doubt seem slow to those not directly involved. It will be difficult for many members of the Institute community to understand the sometimes agonizing process which precedes major changes. Hopefully, constructive change can come rapidly enough to result in strengthening both M.I.T. and the whole academic enterprise.

The reports which follow, written by the Laboratory Directors, demonstrate the intensity and quality of work at the Special Laboratories during the past year.

JACK P. RUINA

## INSTRUMENTATION LABORATORY

Instrumentation Laboratory activities during the year 1968-1969 have been extraordinarily successful from the standpoint of technological achievements. The activity was supported by the U.S. Navy, U.S. Air Force, and U.S. Army, as well as the National Aeronautics and Space Administration (NASA) and various other civilian agencies. The Laboratory has been subject to strong attacks from some students and several faculty groups, ranging from speeches to picketing, with threatened occupation of some Laboratory facilities. Normal work was disrupted during a period of some two months. Under the skillful handling of President Howard W. Johnson, as manifest in his appointment of the review panel and his wise consideration of the panel's recommendations, the situation returned to a reasonable degree of normalcy. Effective research is now continuing.

It is not to be expected that the Instrumentation Laboratory will be free of critical attention from various directions in the future, but it appears that there will be no complete severing of the M.I.T.-Instrumen-

tation Laboratory ties, and that suitable comprehensive tasks of pioneering technology may be accepted in the future without regard to whether or not sponsorship is civilian or military, with or without classification. However, classified projects will be avoided whenever possible, and security restrictions will be minimized in all possible ways. It is agreed that, when adequate support is available, civilian projects will be given preference over military ones unless an overriding national emergency occurs. With judgment and good will from all of the parties involved, M.I.T. and the Instrumentation Laboratory should be able to continue their excellent relationship.

Guidance and navigation for the Apollo Command Module and the Apollo Lunar Excursion Module are spectacular successes for the Instrumentation Laboratory. Manned trips to the moon, with separation and exercise of the Lunar Excursion Module, have both shown that our efforts are theoretically correct and produced designs from which AC Electronics, Raytheon, Kollsman and other companies have produced systems which have worked in space flight operations without significant flaws. With the approach of Apollo 11 to carry out the complete moon landing and return mission, all the Instrumentation Laboratory personnel are to be congratulated on an excellent job, with better-than-specification performance delivered on schedule.

Poseidon guidance systems designed by the Laboratory are now in production. Firing tests with complete missiles have encountered some difficulties, but are now demonstrating excellent performance.

Stabilization and angular control systems for the NASA Orbiting Astronomical Observatory have been designed, built, and have passed laboratory performance tests before being installed in vehicles for flight operations.

Deep submergence rescue submarine systems for control, navigation and guidance have been designed, built in the form of engineering models and delivered to Lockheed Aircraft for sea tests within the next few months. The Laboratory retains a simulator which is being used to train the first crews of hydronauts. The action of the system as demonstrated by the simulator is excellent and appears to have started a train of thought in the Navy that may well revolutionize control arrangements for all submarines and ships.

SEAL, a system based on geometry provided by inertial components, has been built for the Federal Aviation Authority and is now installed in an airplane for shakedown tests. This system is intended to provide geometrical references so accurate that it will be possible to plot radiation field intensities on a map to give consistent locations of radio navigational aids.



Advanced gyro units and specific force integrating sensors have been under engineering study in the Laboratory for two years. The data to be taken under the original arrangement with NASA are now substantially complete. Engineering prototype units are now either under construction or already in test. It appears that the original goal of two orders of magnitude improvement in performance can be achieved. Designs of production prototypes will be started immediately.

Sabre guidance system tests are well along on engineering models, and results are most encouraging. Work is now going forward on new Sabre-type units based on applications of the new inertial sensors. These designs will have improved performance and be smaller in size than the systems now under tests.

A most interesting development in the Laboratory has been the VTOL (Vertical Takeoff and Landing) system being carried out for the Army and NASA by Mr. Ralph Trueblood under the supervision of Professors Rene H. Miller and H. Philip Whitaker. Recent demonstration tests for Army and NASA personnel with a helicopter have been quite successful. It is hoped that this field of control, navigation, and guidance for VTOL craft with its far reaching implications for increased safety in both commercial and military applications will receive more active attention in the immediate future.

Two years ago, with the establishment of the Division of Scientific Technology headed by Laboratory staff member Philip N. Bowditch, the Instrumentation Laboratory formally accepted the responsibility and challenge for emphasizing and expanding interaction and collaboration with scientific and academic interests both within and outside M.I.T. as a significant part of the Instrumentation Laboratory's efforts.

During the past two years, activities within this division have amply demonstrated the potential and interest both inside the Laboratory and in the academic and scientific communities. Projects initiated and continued in the past year include the following: support to the Woods Hole Oceanographic Institute in the engineering problems associated with their major mid-water offshore ocean current program; design, construction, and deployment of a major oceanographic instrumentation array off Bermuda in collaboration with the Center for Earth Sciences; the development, construction, and checkout of novel soil mechanics instrumentation in support of the soil mechanics division of the Department of Civil Engineering; design, engineering, and construction of a bio-telemetric instrumentation system in collaborative support of a project in the Life Sciences Center; a collaborative project with the Department of Metallurgy and the Harvard School of Public Health on computer control of an electron microscope for particulate matter identifica-

tion and monitoring; the engineering, design, and construction and installation of a Beneoff Tiltmeter instrument at the Agassiz Seismology Station in Harvard, Massachusetts, in support of the Department of Earth and Planetary Physics.

The above projects reflect the diverse character of efforts that the Instrumentation Laboratory has participated in during the last year. This listing is not complete, but serves to show the many ways in which a laboratory such as the Instrumentation Laboratory can support and derive benefit from interactions with the scientific and academic community.

One project deserves special mention, as it exemplifies to the Laboratory the desired end objective of continuing collaboration with the M.I.T. campus. This project is called CARS (a demand-responsive public transportation system). The project was conceived and worked on by the students and faculty of several departments under the charter of the Urban Systems Laboratory. During the last year, the Instrumentation Laboratory was invited to participate with the leaders of the project in the Urban Systems Laboratory, as a full collaborator in a major program of implementation of this transportation concept. This project promises to involve a major effort of the Instrumentation Laboratory together with a major involvement of faculty and students from many departments in an exciting and rewarding project of social consequence.

The Instrumentation Laboratory has recently been asked by the Urban Systems Laboratory to collaborate with them in responding to a novel dual mode transportation concept involving the CARS system with a line-haul automated highway link. This effort could well involve a major consortium of academic staff and students, together with full-time professional Instrumentation Laboratory staff and private industries.

The Division of Scientific Technology looks forward in the ensuing year to an increase in this type of inter-community activity, which clearly benefits the laboratory, the campus, and the Institute as a whole.

Support for sponsored research in the Instrumentation Laboratory increased by less than one per cent during the 1968-1969 academic year, as compared with the previous year, the current yearly rate being approximately 54 million dollars. Total personnel, including associated laboratories and industrial assistance, was at about 2,450 on April 1, showing a downward trend of just over 1.5 per cent within the past year.

Education for the full spectrum of students, from undergraduates through graduates and postgraduates concerned with bridging the gap between academic studies and professional practice, has continued to be a major concern of the Laboratory. This activity, as in past years, was made very effective by the long-established position of the Laboratory as an integral part of the Department of Aeronautics and Astronautics.

During April approximately 398 students, ranging from freshmen to candidates for doctoral degrees, were associated in some significant way with the Laboratory. During the same month, 77 members of the Laboratory staff were enrolled as special students at M.I.T., and 81 others were taking courses at outside schools. During the year, 39 students carried out thesis work in the Laboratory under the supervision of faculty members and staff engineers. Of these students, 19 accomplished research at the doctoral level, 18 worked on Master's theses, and 2 concerned themselves with Bachelor's theses. A total of 24 degrees were granted at the June graduation to members of these groups.

In addition to providing facilities and teaching help for regular academic activities, the Laboratory employed 157 students in part-time work during April, a typical month.

Classification of reports and equipment produced by the Laboratory is involved in about 25 of the 46 existing contracts. It is usual for these contracts to contain provisions allowing access to pertinent restricted information and specifying certain limited categories of data and design results that must be subject to security regulations. In practice, classification has interfered very little with educational activities of the Laboratory. For example, out of 11 theses accepted during a typical period between July and December, 1968, none were classified. Among Laboratory reports issued during the last six months of 1968, a representative sample numbered 104, of which 37 were classified, 17 as secret and 20 as confidential. The total number of pages involved was 15,821, of which 1.8 per cent were classified. Considering both the Laboratory reports and academic writing of some 17,329 pages, classification was involved for only 1.5 per cent. As a matter of general policy, all classified material is reviewed at intervals and cleared as soon as this action is possible.

Faculty members of the Department of Aeronautics and Astronautics have continued to provide general direction for Laboratory activities and to incorporate information and experience derived from developments of advanced technology into the body of engineering education. Institute Professor Emeritus Draper continued to serve as the Laboratory Director, with Professor Wrigley as Educational Director. Department faculty members associated with Professor Wrigley in academic activities included Professors John J. Deyst, Robert L. Halfman, Francis X. Harrington, Walter M. Hollister, Yao T. Li, Winston R. Markey, Walter McKay, Jacob L. Meiry, Robert K. Mueller, James E. Potter, Wallace E. Vander Velde, H. Philip Whitaker and Laurence R. Young. From the Laboratory staff, Doctors Richard H. Battin and Robert G. Stern served as Lecturers, taking responsibility for teaching subjects in Aeronautics and Astronautics. Roger B. Woodbury, Forrest E. Houston, and Ralph R. Ragan

continued to serve as Deputy Directors, with Joshua B. Feldman as Executive Officer.

C. STARK DRAPER

### LINCOLN LABORATORY

To all three major objectives of the institute — education, research, and public service — the Lincoln Laboratory has contributed, but perhaps most significantly to public service. In this connection it should be remembered that the year was marked by a major national debate on the need for the Anti-Ballistic Missile. The results of the Laboratory's measurements, analysis, and evaluation of ballistic missile systems for the civilian and military agencies of the Department of Defense provided the national decision makers with objective and relevant information.

The year also has been marked by a re-examination of the national civil and military priorities and of the role of the university. On our own campus, the Review Panel on Special Laboratories studied and debated the current and future relationship of the Laboratories to M.I.T. The recommendations of the panel will serve as a catalyst for the creation of new joint educational and research activities and for exploration of new projects that will bring the Institute's public service efforts to better balance with national priorities.

Toward this end, the panel's study disclosed the need for better understanding between the Laboratory and the campus about changing aims and objectives. The panel's discussions greatly helped to improve this understanding, and we are turning our efforts to establish more permanent means of interaction.

Yet Lincoln Laboratory has continued to have many points of contact with the Institute community on technical matters. In the course of the past year, we had more than 2800 visits from faculty and students, representing 66 educational institutions, 1788 visits from consultants (many of whom are academic faculty members), and more than 11,000 visits by personnel from almost 1100 different companies. It is of some interest to note that 94 per cent of the academic visits and 71 per cent of the industrial visits were unclassified and required no security clearance. In addition, members of the Laboratory presented 447 papers at professional meetings all over the world and published 205 journal articles. In the past academic year, 135 members of the Laboratory took courses with the support of M.I.T. Tuition Assistance Plan, and this summer we have 31 M.I.T. faculty members and graduate students on our summer staff.

### ADMINISTRATION

Two developments this year were particularly consonant with the Review Panel's recommendations for increased nondefense research and ex-

panded educational interactions, though both originated well before the panel was established.

Our entire Seismic Discrimination group has moved to Cambridge to take up residence in the newly finished Seismic Data Center in Building E34, where we can work more closely with faculty, fellows, research assistants, and students of the Department of Earth and Planetary Sciences. The move took place in the spring, and we look forward to increased academic participation in this program during the fall term. The computation and display facilities have been significantly improved during the past year, and we have developed considerably better programs for flexible, interactive processing and manipulation of geophysical data. The Center continues to receive data from the large seismic arrays in Montana and Norway, as well as from other sources. There has been recent interest in using our facilities for an analysis and interpretation of seismic data from the instrument placed on the lunar surface by the Apollo 11 crew and for processing oceanographic data, as well as seismic data.

Last year, we reported on a cooperative program, initiated several years ago, to define and develop techniques to improve ambulatory health care. The first phase of this work received support from the Commonwealth Fund through the Commissioner of Health, Hospital, and Welfare of the City of Cambridge; it generated in January a detailed report on "A Program for an Ambulatory Health Care Service." This program calls for technological aids for taking, storing, and retrieving medical records and for a computer-aided diagnostic system. On the basis of this report, a joint effort by Lincoln Laboratory and the Beth Israel Hospital is now under way, sponsored by the Department of Health, Education, and Welfare (HEW) to develop and demonstrate the initial technical components for such a program.

Also funded by HEW and initiated about a year ago is a small program to demonstrate the use of computer assistance in gaining rapid and convenient access to the huge data files of the National Library of Medicine. This program is implementing an on-line information storage and retrieval system called LISTAR, operating on the Lincoln Laboratory time-sharing computer system, which permits the library staff to search and modify a Medical Subject Heading file of 10,000 entries from a terminal at the library in Bethesda, Maryland.

#### INTERNAL REORGANIZATION

Early in 1969, a new Optics division was formed from one of our Solid State groups and two Radio Physics groups principally concerned with optical re-entry measurements. More recently, another new division has been established, one division reconstituted, and other groups relocated

within our existing divisional structure. The objectives of this reorganization are to simplify administration of our applied research projects and to provide closer personal and professional relations among technical personnel working on different aspects of the same project. With very few exceptions, internal group structure has been maintained essentially intact.

Re-entry systems engineering, testing, and evaluation is now consolidated in the new Aerospace division, made up of three groups that were previously parts of the Data Systems division. The Radio Physics division has been reconstituted into a re-entry Radar Measurements division, with the addition of four groups from the Radar division and the transfer of the Millstone-Haystack group to Data Systems. Also transferred into Data Systems was the Seismic Discrimination group (formerly in Communications); both of these groups require large-scale data processing capabilities, and both have particularly close ties with the campus.

We now have nine divisions: Administrative, Data Systems, Radar Measurements, Radar, Optics, Communications, Engineering, Solid State, and Aerospace.

#### **SPONSORSHIP**

The organizational changes outlined above reflect the accomplishment of certain changes in sponsorship anticipated in our report last year. The Army has taken over from the Advanced Research Projects Agency (ARPA) of the Department of Defense the sponsorship of re-entry radar development and measurements, formerly called Radar Discrimination Technology and Project PRESS, respectively. ARPA continues to sponsor the PRESS optical re-entry measurements, together with laser radar technology development, computer graphics, seismic discrimination, and certain systems studies. The Air Force continues to sponsor our Space Communications, General Research, and Re-entry Systems programs. The Navy sponsors research relevant to world-wide communication techniques.

#### **MAJOR APPOINTMENTS**

Dr. Gerald P. Dinneen, previously Assistant Director, was appointed Associate Director; Mr. Jerome Freedman and Mr. Walter E. Morrow, Jr., previously Division Heads in Radar and Communications respectively, were appointed Assistant Directors. Mr. C. Robert Wieser, Deputy Director of the Laboratory, was granted a leave of absence to serve as Assistant Director of Defense Research and Engineering (Defensive Systems) in the Office of the Secretary of Defense.

Mr. Herbert G. Weiss and Mr. Paul Rosen were appointed Heads of

the Radar and Communications divisions, and Dr. V. Alexander Nedzel was appointed Head of the Aerospace division. Prof. John M. Wozencraft of the M.I.T. Department of Electrical Engineering was appointed Associate Head of our Communications division. Dr. John L. Allen and Dr. Robert H. Kingston, previously Group Leaders, were appointed Associate Heads of the Radar Measurements and Optics divisions. Dr. Melvin A. Herlin was transferred from the Radio Physics division to the Data Systems division as Associate Head.

Prof. Alan L. McWhorter of the Department of Electrical Engineering temporarily relinquished his position as Head of our Solid State division to organize the newly formed Optics division. Dr. Kingston has now been appointed Head of the Optics division, and Prof. McWhorter will again be Head of the Solid State division; Dr. Peter E. Tannenwald has been Acting Head in the interim.

Two members of our staff have joined the M.I.T. faculty this year. Mildred E. Dresselhaus of our Solid State division, previously Visiting Professor in the Department of Electrical Engineering, was appointed Professor in June 1968, and William J. Ince of our Radar Division is being appointed Assistant Professor in the same Department in July 1969.

#### **SOME TECHNICAL HIGHLIGHTS**

Lincoln Experimental Satellite LES-6, launched in September 1968, has been in many ways the most significant of our communications satellites to date. Its predecessor LES-5, launched July 1967, provided the means for the first feasibility demonstration of clear, direct, dependable communication via satellite, over long or short distances, among compact surface terminals mounted on ships and submarines at sea, aircraft in flight, and mobile and portable ground terminals. LES-6, with considerably greater effective radiated power than LES-5 and located in a stationary synchronous-orbit position, has made such communication more effective, within its coverage area. Perhaps the clearest measure of the acceptance of satellite communication among small terminals was its designation as the prime communication technique during the Apollo 11 recovery, supplanting traditional HF radio communication. This change resulted from highly successful tests with LES-6 during earlier Apollo recoveries; the Apollo 11 recovery communication net used the Air Force TACSAT 1 satellite that was launched in February as the operational successor of LES-6, with LES-6 standing by in case of need.

Many technological innovations aboard LES-6 may have significant influences on the design of future spacecraft. These include the first circularly polarized, electronically despun antenna system, the first auton-

omous east-west station-keeping system on a synchronous-orbit satellite, and a unique power-optimized UHF-band power amplifier chain. Of particular interest is the first useful long-lifetime electrically powered thruster system, which has kept the satellite at a prescribed position in orbit for more than six months; this is of special importance to the long-term development of space propulsion, since arc thrusters do not require the payload penalty associated with chemical propellants.

These and other operating systems on LES-6, in combination with experiments to measure solar cell degradation, earth albedo, and UHF-band radio interference, are providing valuable information and experience for spacecraft design. Meanwhile, there has been comparable progress in the development of ground terminal equipment, including a low-data-rate (2400 bits per second) vocoder and new versions of our TATS frequency-hopping modulation-demodulation system.

Large-scale improvements have been and are being made in our re-entry measurements facilities on the Kwajalein Missile Range in the Pacific. Installation of the new ALTAIR UHF/VHF radar system has been completed by the manufacturer, and it has been turned over to Lincoln Laboratory for shakedown testing and initial operation. The new ALCOR C-band radar system is also in the process of shakedown testing and has achieved its first successful tracking of ballistic targets. Performance requirements and specifications have been prepared, and a contract awarded, to upgrade the operation of the existing TRADEX radar at L-band frequencies and to add S-band capability as well. These facilities on Roi-Namur Island were officially named the Kiernan Re-Entry Measurements Site (KREMS) at a ceremony in Washington on May 19 in honor of Lt. Col. Joseph M. Kiernan Jr., USA, who was instrumental in their early development.

A 20-inch aperture Airborne Infrared Telescope developed at Lincoln was added to the optical instrumentation on the KC-135 aircraft used for re-entry measurements at Kwajalein. At Millstone Hill, we have established a new Firepond Infrared Research Facility for experiments in passive and active optical observations of aircraft and satellites. One of the principal instruments at this facility, a 1000-watt CW carbon dioxide laser radar, has been installed and preliminary experimental operation has begun. Tests of the doppler system on aircraft targets were carried out at reduced power levels. In the laboratory, the ability of a coherent doppler imaging system, using a carbon dioxide laser as a source, to distinguish moving targets from background clutter was successfully demonstrated.

Our General Research program in Solid State yielded many results relevant or directly applicable to the Optics work noted above. For



example, the Faraday rotation in highly transparent single crystals of ferromagnetic europium oxide was measured at wavelengths between 1.5 and 20 micrometers, with results that indicated that this material holds considerable promise for use in circulators and isolators in carbon dioxide laser radar systems. Also, temperature and magnetic field tuning of laser emission from lead-tin selenide diodes, which may be used for optical heterodyning, was achieved and studied in a range of compositions at wavelengths from 8.5 to 34 micrometers. More generally, experimental and theoretical investigations of semiconductors, metals, and other materials led to increased understanding of their properties and suggested some possible new device applications. Optically excited light emission from metals was observed for the first time, for example, providing a powerful new tool for studying the band structure of metals. Also, efficient room-temperature photoluminescence over most of the visible spectrum was obtained in zinc sulfide-cadmium sulfide alloys doped with tellurium.

Utilization of our IBM 360/67 time-sharing system has increased steadily. The number of user accounts has jumped from 90 to 150, and the number of terminals has increased by more than 20 per cent. There are now 66 terminals distributed throughout the Laboratory and at remote locations which include the National Library of Medicine in Bethesda, Maryland, our Haystack facility in Tyngsboro, the Seismic Data Center on the Cambridge campus, our field office at Norton Air Force Base in California, the Beth Israel Hospital in Boston, and two at Harvard University. The system is now in operation for fourteen hours a day and is almost invariably full to its present capacity of 32 simultaneous users at all times during regular working hours.

Our Radio and Radar Astronomy program has benefited from increased participation by students and faculty from M.I.T. and Harvard and from the substantial collaboration between our Haystack and Millstone facilities and other radio and radar observatories throughout the world. Radar measurements of planetary topography showed 12-kilometer variations on Mars, and 1-kilometer variations on Mercury (on a continental scale). Similar measurements indicated Venus to be "out of round" by approximately 2 kilometers. Monostatic and interferometric radar measurements shed new light on particular features of the hidden surface of Venus and gave the first substantive evidence of significant altitude variations. Several important physical parameters were confirmed with smaller probable errors than have previously been attained: the general relativistic advance of Mercury's perihelion to within 1.2 per cent; the general relativistic retardation of radar waves by the sun's gravitation to within 6 per cent; and Mercury's mass to within 0.1 per

cent. Radio studies of interstellar molecules resulted in the detection of three new sources of water-vapor emission and established the near-coincidence of the positions of eight hydroxyl (OH) and water-vapor sources. Several new OH sources associated with infrared stars were observed with a very-long-baseline interferometer between Haystack and the National Radio Astronomy Observatory in Greenbank, West Virginia.

MILTON U. CLAUSER

## **VICE PRESIDENT AND TREASURER<sup>1</sup>**

The increase in operations of the Institute in 1968-69 to \$218,000,000 represents a two per cent advance which compares with increases of seven per cent in 1967-68 and twelve per cent in 1966-67. The Sources of Revenues and Funds to meet Expenses of Current Operations which follows summarizes the educational and general and sponsored research operations for 1968-69 and 1967-68. The Balance Sheets on pages 696 and 697 compare the total financial and plant resources on June 30, 1969, with the resources on June 30, 1968. The main increase in the balance sheet assets from \$417,844,000 to \$452,202,000 in 1968-69 was in the invested funds of M.I.T. The statement of changes in funds on pages 700-701 details the additions and reductions in the funds of the Institute during the year 1968-69.

### **OPERATIONS**

As shown in the table below, there was an increase of five per cent in educational and general expenses during the year which was attributable primarily to adjustments in salaries and wages and related benefits over the preceding year. Departmental sponsored research was practically unchanged and the operation of the major laboratories in 1968-69 changed very slightly from 1967-68.

<sup>1</sup>The complete report of the Vice President and Treasurer, including schedules supporting those printed on the following pages; the list of gifts, grants, and bequests received during the year 1968-69; and reports of the Trustees of the M.I.T. Pension Association, Supplementary Retirement Plans and the Retirement Plan for Employees, is published separately and may be obtained on request from the Office of the Treasurer.

VICE PRESIDENT AND TREASURER

	1968-69	1967-68
Educational and general expenses	\$ 57,355,000	\$ 54,652,000
Direct expenses of general departmental and interdepartmental sponsored research	45,812,000	45,680,000
Direct expenses of major laboratories and special departmental research	108,010,000	106,678,000

While academic and administrative expenses included within educational and general expenses increased over the level of 1968, there was a reduction in plant operating expenses in 1968-69 due to a decrease in special alterations and maintenance expenses, although normal plant operating expenses continued to expand with the greater size of the plant of the Institute. The increase in educational and general expenses was financed by larger tuition revenues, greater endowment investment income, and higher contract allowances for general and administrative and plant expenses. Unrestricted resources available on a limited basis have been allocated in increasing amounts in 1968-69 and in recent years to finance specified continuing operating expenses.

GIFTS

Gifts, grants, and bequests in 1968-69 and 1967-68 were received as follows:

	1968-69	1967-68
Gifts for endowment	\$ 4,595,000	\$ 6,619,000
Gifts for buildings	2,540,000	2,641,000
Gifts for current use — invested	13,367,000	8,521,000
Industrial Liaison Program	1,601,000	1,255,000
Other funds for current use	2,966,000	3,111,000
Total gifts to funds	<b>\$25,069,000</b>	<b>\$22,147,000</b>
Grants-in-aid	4,583,000	3,734,000
Total	<b>\$29,652,000</b>	<b>\$25,881,000</b>

The support of special programs under the supervision of the academic departments by private foundations was an important source of the grants included as gifts for current use — invested. A substantial proportion of the increase over the previous year was provided by the distribution of a part of a bequest ultimately to be allocated to buildings and endowment. Professorships and undergraduate scholarships and building maintenance funds were important in the total of gifts for endowment in 1968-69. The gifts, grants, and bequests in 1968-69 were exceeded in only one earlier year when much of the bequest by Alfred P. Sloan, Jr. was distributed to the Institute.

#### VICE PRESIDENT AND TREASURER

The unrestricted direct gifts to the Alumni Fund of \$744,000 are included in the total of \$2,680,000 credited by the Alumni Fund in 1968-69.

#### FUNDS

The total funds of the Institute on June 30, 1969 were \$290,598,000 compared with \$259,882,000 on June 30, 1968.

	1968-69	1967-68
Endowment for general purposes	\$ 62,635,000	\$ 61,932,000
Endowment for designated purposes	79,812,000	73,237,000
<b>Total endowment funds</b>	<b>\$142,447,000</b>	<b>\$135,169,000</b>
Building and expendable funds	76,072,000	69,674,000
Other funds	72,079,000	55,039,000
<b>Total funds</b>	<b>\$290,598,000</b>	<b>\$259,882,000</b>

Of the total increase in funds of \$30,800,000 during 1968-69, \$7,356,000 was in endowment resources, \$6,398,000 in building and expendable funds, and \$17,046,000 in other funds. A further receipt for the Basic Research Fund in the Physical Sciences was included in the expendable funds. An expendable fund of more than \$6,000,000 will later be transferred to the capital resources of the Institute. The increase in other funds was related largely to the net realized gains on securities during the year of \$13,068,000 compared with \$9,221,000 in 1967-68. The general investments gain and loss account on June 30, 1969, was \$27,407,000, up from \$14,454,000 on June 30, 1968. Including the retirement funds, the book value of the funds on June 30, 1969, was \$381,020,000. The investment income for distribution to funds on June 30, 1969, was \$17,714,000, and on June 30, 1968, was \$16,445,000.

#### PLANT

The book value of the educational plant of the Institute increased from \$120,197,000 to \$127,521,000. Additions to the plant represented primarily buildings in the process of construction, including the Dreyfus Chemistry Building, MacGregor House, the Engineering Library in Building 10, the Information Processing Center building, and further construction on the Hydrodynamics Laboratory building and the Center for Advanced Engineering Study. During 1968-69, a debt service agreement was initiated but not completed with the Department of Housing and Urban Development for a part of the cost of an addition to the Westgate housing project.

On June 30, 1969, approximately nine per cent of the book value of the plant was financed with loans from private and government sources.

VICE PRESIDENT AND TREASURER

The advance from general cash resources of the Institute on a temporary basis for construction in process was \$3,059,000, compared with \$2,725,000 on June 30, 1968.

**INVESTMENTS**

The investments of the Institute on June 30, 1969, and June 30, 1968, are presented in the following table, which does not include the separately invested retirement funds.

	June 30, 1969		June 30, 1968	
	Book Value	Market Value	Book Value	Market Value
<b>General investments:</b>				
Fixed income	\$107,268,000	\$ 92,537,000	\$110,716,000	\$100,553,000
Equity	86,850,000	178,080,000	65,381,000	174,693,000
Real estate	21,767,000	21,767,000	20,313,000	20,313,000
<b>Total</b>	<b>\$215,885,000</b>	<b>\$292,384,000</b>	<b>\$196,410,000</b>	<b>\$295,559,000</b>
Special investments	49,584,000	54,568,000	40,778,000	49,915,000
Students' notes receivable	10,831,000	10,831,000	9,270,000	9,270,000
<b>Total</b>	<b>\$276,300,000</b>	<b>\$357,783,000</b>	<b>\$246,458,000</b>	<b>\$354,744,000</b>

Funds sharing in the income from the general investments earned 6.89 per cent. Five per cent was allocated to the endowment funds plus an extra distribution of two per cent in 1968-69. The income distribution to the other funds was at the same rates and on the same basis as in prior years. Of the total investment income for the year, \$7,351,000 was used directly for current expenses; \$3,115,000 was added to balances of expendable funds, which in turn were used for current operating expenses to the extent of \$4,069,000; and \$2,047,000 was added to the funds for scholarships, loans, and buildings. The total investment income for the year on the general and separately invested funds was \$14,579,000 compared with \$13,502,000 in 1967-68 and \$12,788,000 in 1966-67.

The investments of the M.I.T. Pension Association, the Supplementary Retirement Plans, and the Retirement Plan for Employees on June 30, 1969, and June 30, 1968, are presented on the following page.

**RETIREMENT FUNDS**

The retirement funds of the Institute are under the supervision of the trustees of these plans. While the retirement funds are neither commingled with those of the Institute nor reflected in its financial statements, there is an important financial coupling between the retirement funds and the finances of M.I.T. The pension expense included in operations in 1968-69 was \$6,690,000 compared with \$6,268,000 in 1967-68, including the amortization of past service costs. During 1969 the Institute

VICE PRESIDENT AND TREASURER

	June 30, 1969		June 30, 1968	
	Book Value	Market Value	Book Value	Market Value
Pension Association	\$ 40,767,000	\$ 42,497,000	\$ 36,041,000	\$ 41,428,000
Supplementary Retirement Plan — Fixed Benefit	21,544,000	19,889,000	18,775,000	18,567,000
Supplementary Retirement Plan — Variable Benefit	9,387,000	10,174,000	8,009,000	9,059,000
Retirement Plan for Employees	18,640,000	16,255,000	16,481,000	15,125,000
<b>Total</b>	<b>\$ 90,338,000</b>	<b>\$ 88,815,000</b>	<b>\$ 79,306,000</b>	<b>\$ 84,179,000</b>

for the first time recognized in part realized and unrealized appreciation and depreciation of retirement fund investments in the determination of contributions by M.I.T. to the pension plans. Because pension costs were increased, this change did not significantly affect 1968-69 pension expense. Fixed income securities held by the retirement funds are shown in this report at book and market values rather than statutory values often exhibited and required in some fiduciary institutional accounting. With interest rates on bonds in 1968-69 at the highest level in nearly a century, the lowered prices of earlier-issued bonds reflect this extraordinary development of recent years. In comparing market values with book values of the retirement funds, it should be emphasized that these funds, while continuing to accumulate from year to year, for the most part will not be withdrawn except over long periods of time in the future and are essentially invested, therefore, with the major emphasis on long-term results. After careful consideration of the projected cash receipts and cash disbursements of the retirement funds, the trustees have gradually and moderately increased the proportions of the funds in common stocks.

GENERAL

During the year the accounting for investments was revised to include three main pooled funds. The first of these commingled accounts will include primarily funds contributed to the Institute as endowment; the second will be a pool of endowment and similar funds representing largely unrestricted funds allocated by the Corporation to endowment; and the third commingled account will consist of funds held for investment for the most part over short to intermediate periods, but extending out possibly as long as ten years. Through this change, the management of the investments should be facilitated and investment results more clearly identified.

JOSEPH J. SNYDER

VICE PRESIDENT AND TREASURER

**Schedule A: BALANCE SHEETS, JUNE 30, 1969**

**CURRENT AND DEFERRED ASSETS**

Cash:		1969
General purposes .....	\$	1,223,000
Restricted, principally to research activities .....		6,418,000
Accounts receivable:		
U.S. Government .....	(A-14)	2,736,000
Other .....	(A-14)	4,257,000
Contracts in progress, principally U.S. Government		
	(A-15)	17,206,000
Inventories, deferred charges and other assets (A-16)		10,018,000
		<u>\$ 41,858,000</u>

**INVESTMENTS**

General investments, at cost:		
Fixed income securities .....		\$107,268,000
Equity securities .....		86,850,000
Real estate (including \$5,793,000 devoted to Institute use) .....		21,767,000
	(A-1)	<u>\$215,885,000</u>
Investments of separately invested funds .....	(A-2)	49,584,000
Students' notes receivable .....	(A-13)	10,831,000
Total investments .....		<u>\$276,300,000</u>
Cash held for investment .....		4,167,000
Receivables from sales of securities .....		2,356,000
		<u>\$282,823,000*</u>

**EDUCATIONAL PLANT**

Land, buildings, and equipment, at cost .....	(A-20)	\$126,691,000
Construction in progress .....		774,000
Temporary investment and cash .....		56,000
		<u>\$127,521,000</u>
		<u>\$452,202,000</u>

\*Total market, including real estate investments at cost, \$357,783,000.



VICE PRESIDENT AND TREASURER

Schedule A: **BALANCE SHEETS, JUNE 30, 1969**

<b>CURRENT LIABILITIES AND FUNDS</b>	1969
Accounts payable and accruals .....	\$ 11,427,000
Withholdings, deposits, and other credits ..... (A-17)	4,088,000
Advances by the U.S. Government for certain research contracts and grants .....	18,666,000
Unexpended grants for sponsored research from private sources .....	2,961,000
Gifts and other receipts available for current expenses (A-19)	7,775,000
Funds advanced for educational plant .....	(3,059,000)
	<u>\$ 41,858,000</u>
 <b>INVESTED FUNDS</b>	
Endowment funds:	
Income for general purposes ..... (A-3)	\$ 62,635,000
Income for designated purposes ..... (A-4)	79,812,000
Student loan funds ..... (A-5)	10,896,000
Building funds ..... (A-6)	4,120,000
Other expendable funds:	
General purposes ..... (A-7)	12,704,000
Designated purposes ..... (A-8)	59,248,000
Unexpended endowment income for designated purposes ..... (A-4)	4,127,000
Agency funds ..... (A-9)	678,000
Funds subject to life interests in income ..... (A-10)	3,482,000
General investments — gain and loss account (A-11)	27,407,000
Investment income for distribution to funds .... (A-12)	17,714,000
	<u>\$282,823,000</u>
 <b>EDUCATIONAL PLANT LIABILITIES AND FUNDS</b>	
Mortgage bonds and notes payable ..... (A-21)	\$ 11,699,000
Advanced from current funds .....	3,059,000
Funds used for educational plant ..... (A-22)	112,763,000
	<u>\$127,521,000</u>
	<u>\$452,202,000</u>

The explanation of pension costs which appears on page 694 and the data in Schedule A-21 are an integral part of these financial statements.

VICE PRESIDENT AND TREASURER

**Schedule B: SOURCES OF REVENUES AND FUNDS  
USED TO MEET EXPENSES OF CURRENT OPERATION**

FOR THE YEAR ENDED JUNE 30, 1969

**EDUCATIONAL AND GENERAL**

**EXPENSES OF CURRENT OPERATION**

		1969
Academic departments .....	(B-4)	\$ 25,567,000
General and administration .....	(B-5)	13,603,000
Student activities, general and plant expenses, and major dormitory repairs .....	(B-6)	2,341,000
Plant operation .....	(B-7)	9,878,000
Auxiliary activities .....	(B-8)	5,966,000
		<u>\$ 57,355,000</u>
Less contract allowances for general and administration, and plant operation expenses (see below) .....	(B-3)	16,056,000
		<u>\$ 41,299,000</u>

**SOURCES OF REVENUES AND FUNDS USED**

**REVENUES**

Tuition and other income .....	(B-1)	\$ 17,638,000
Auxiliary activities .....	(B-8)	5,966,000
		<u>23,604,000</u>

**FUNDS USED**

Endowment investment income .....	(B-2)	\$ 7,351,000
Gifts, investment income and other receipts .....	(B-2)	10,344,000
		<u>17,695,000</u>
		<u>\$ 41,299,000</u>

**SPONSORED RESEARCH**

**EXPENSES**

Salaries and wages .....	(B-3)	\$ 64,881,000
Pension and other employee benefit costs .....	(B-3)	8,423,000
Materials and services .....	(B-3)	44,615,000
Subcontracts .....	(B-3)	33,021,000
Travel .....	(B-3)	2,882,000
Research general and administration expenses .....	(B-3)	5,052,000
Allowances for general and administration, and plant operation expenses (see above) .....	(B-3)	16,056,000
Allowance for use of facilities and other reserves ...	(B-3)	1,276,000
		<u>\$176,206,000</u>

**REVENUES**

General departmental and interdepartmental research ...		\$ 55,257,000
Major laboratories and special departmental research:		
Lincoln Laboratory .....		66,833,000
Instrumentation Laboratory .....		54,116,000
	(B-3)	<u>\$176,206,000</u>

<b>Total operations .....</b>		<b><u>\$217,505,000</u></b>
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The explanation of pension costs which appears on page 694 and the data in Schedule A-21 are an integral part of these financial statements.

VICE PRESIDENT AND TREASURER

**AUDITOR'S CERTIFICATE**

**TO THE AUDITING COMMITTEE OF THE  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY:**

We have examined the financial statements of Massachusetts Institute of Technology:

Schedule A — Balance Sheets as of June 30, 1969.

Schedule B — Sources of Revenues and Funds Used to Meet Expenses of Current Operation for the Year Ended June 30, 1969.

Schedule C — Statement of Funds for the Year Ended June 30, 1969.

Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. We used auditing procedures other than direct confirmation to establish the validity of certain U.S. Government receivables. We previously examined and reported upon the financial statements of Massachusetts Institute of Technology for the year ended June 30, 1968.

In our opinion, said statements present fairly the financial position of Massachusetts Institute of Technology at June 30, 1969, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a consistent basis.

LYBRAND, ROSS BROS. & MONTGOMERY

Boston, Massachusetts, September 12, 1969

**REPORT OF THE AUDITING COMMITTEE**

**TO THE CORPORATION OF THE MASSACHUSETTS INSTITUTE OF  
TECHNOLOGY:**

The Auditing Committee reports that Lybrand, Ross Bros. & Montgomery were engaged to make an audit of the books and accounts of the Institute for the fiscal year ended June 30, 1969, and their certificate is submitted herewith.

*Respectfully,*

FRANK R. MILLIKEN  
GILBERT M. RODDY  
DAVID A. SHEPARD, *Chairman*

VICE PRESIDENT AND TREASURER

Schedule C: **STATEMENT OF FUNDS**

FOR THE YEAR ENDED JUNE 30, 1969

	Balance June 30, 1968	Gifts an Other Receipt
Endowment funds:		
Income for general purposes .....	\$ 61,932,000	\$ 658,000
Income for designated purposes .....	73,237,000	5,109,000
Student loan funds .....	10,242,000	828,000
Building funds .....	6,764,000	4,762,000
Other expendable funds:		
General purposes .....	6,542,000	8,721,000
Designated purposes .....	56,368,000	7,965,000
Unexpended endowment income for designated purposes	3,771,000	.....
Agency funds .....	617,000	60,000
Funds subject to life interests in income .....	3,069,000	406,000
General investments — gain and loss account .....	14,454,000	12,953,000
Investment income for distribution to funds .....	16,445,000	96,000
	<u>\$253,441,000</u>	<u>\$41,558,000</u>
Gifts and other receipts for current expenses .....	6,441,000	11,128,000
	<u>\$259,882,000</u>	<u>\$52,686,000</u>
Gifts received during the year added to funds .....		\$25,069,000
Royalties received net of related costs .....		1,772,000
Receipts from foundations and agencies for student aid .....		4,624,000
Net gain on sales or exchange of investments .....		14,068,000
Appropriations from research contract allowances .....		1,405,000
Government construction grants .....		2,188,000
Fees, services and other receipts .....		3,560,000
		<u>\$52,686,000</u>
Endowment investment income used to meet expenses of current operations .....		
Gifts, investment income and other receipts used to meet expenses of current operation		
Scholarship and fellowship awards for tuition and stipends .....		
Expenditures for buildings added to educational plant .....		
Expenditures of service activities and other charges to funds not representing operating		

\*Investment income on endowment funds for designated purposes is included under the cap

The explanation of pension costs which appears on page 694 and the data in Schedule A-21 are an integri

VICE PRESIDENT AND TREASURER

Investment Income	Transfers In-(Out)	Expenses	Other Charges	Balance June 30, 1969
\$ 4,351,000	\$ (1,000)	\$ 4,305,000	.....	\$ 62,635,000
*	1,466,000	.....	.....	79,812,000
29,000	(66,000)	130,000	\$ 7,000	10,896,000
265,000	(271,000)	46,000	7,354,000	4,120,000
289,000	(1,238,000)	1,075,000	535,000	12,704,000
2,827,000	(1,404,000)	2,994,000	3,514,000	59,248,000
5,461,000	(665,000)	3,046,000	1,394,000	4,127,000
30,000	1,000	.....	30,000	678,000
154,000	(3,000)	.....	144,000	3,482,000
.....	.....	.....	.....	27,407,000
{ (10,901,100) }	.....	.....	.....	17,714,000
{ 12,074,000 }	.....	.....	.....	.....
<b>\$14,579,000</b>	<b>\$(2,181,000)</b>	<b>\$11,596,000</b>	<b>\$12,978,000</b>	<b>\$282,823,000</b>
.....	2,181,000	6,099,000	5,876,000	7,775,000
<b>\$14,579,000</b>	.....	<b>\$17,695,000</b>	<b>\$18,854,000</b>	<b>\$290,598,000</b>

.....	\$ 7,351,000
.....	10,344,000
	<b>\$17,695,000</b>
.....	\$ 7,279,000
.....	7,067,000
Expenses.....	4,508,000
	<b>\$18,854,000</b>

Unexpended endowment income for designated purposes."

Part of these financial statements.



## VICE PRESIDENT, OPERATIONS

The past year has seen both an expansion and contraction in the number of administrative offices responsible to the Vice President, Operations. These changes include the establishment of the Opportunity Development Office, and, at mid-year, the shift of this office and that of Personnel to the Vice President, Academic Administration. These changes represent a constructive effort to serve the M.I.T. community more effectively and to accomplish its goals. The offices which are responsible administratively to the Office of the Vice President, Operations, are those whose detailed reports follow: Physical Plant, Safety, Campus Patrol, Graphic Arts (including Audio-Visual Service), Housing and Dining, and Endicott House. The reports of the Opportunity Development Office and Personnel will be found elsewhere.

The concern which we all share over the employment opportunities for minority group members led to the creation of the position of Opportunity Development Officer. Our natural tendency to deal with these problems from the narrow perspective of our own operating groups created a need for a person to bring together and to provide guidance to the divergent programs of the Institute in this area. It was my privilege to engage James C. Allison Jr. to fill this position and to aid and support him in the establishment of his office and program. The results of his first year at M.I.T. and the work of the President's Task Force on Equal Opportunity are just now reaching the point of a tangible "result oriented" program.

Historically, the personnel function has been split into an academic portion handled by the Office of the Vice President, Academic Administration, and a nonacademic portion handled by the Personnel Office, re-

porting to the Vice President, Operations and Personnel. During the seven years in which the Personnel Office reported to me, the growth of the Institute and the improvement and increased complexity of employee benefits has tended to erode the distinction between academic and non-academic personnel administration. Thus, with a conscious effort to provide a more unified approach to personnel policy within the Institute, this responsibility has been transferred to the Vice President, Academic Administration. As the work of the Opportunity Development Office requires a close, day-to-day working relationship with Personnel, the responsibility for this office was also transferred.

No report on my part would be complete without mentioning the work of the people who met with me for more than a year on the problem of the M.I.T. community's housing needs. The views of the Dean for Student Affairs, and the Offices of Housing and Dining, Planning, Physical Plant, and the Treasurer were brought to bear on the development and evaluation of housing plans that could, from a practical standpoint, be accomplished within the next few years. The results of this effort were seen in the announcement, by Dr. James R. Killian, Jr., and President Howard W. Johnson, of a two-part plan that will provide 800 more campus residential units and 1,600 new dwelling units for Cambridge residents. At this point, planning and development are well under way on both aspects of the plan.

In the past year, characterized by activism and calls for examination and change, there were numerous occasions that demanded of the Campus Patrol unusual skill and devotion to the overall welfare of the campus community. To all these situations they responded with exceptional effectiveness and tact.

Operationally, several highlights from the reports that follow bear further emphasis here. They are:

1. Final planning and design work are under way on a new electrical engineering facility, a graduate student residence on the West Campus, the remodeling of Burton-Conner, and for a new undergraduate residence adjacent to MacGregor House.
2. We have reached a point where the growth of facilities requires major addition to the capacity of both the central heating and chilled water plants and their associated distribution systems.
3. A commitment has been made to convert the existing telephone system to CENTREX within the next three years. At that time the present system will have reached its maximum capacity.
4. Cost escalation in all our construction work has well outstripped inflation. During the last twelve months costs have risen some 10 per cent.

PHILIP A. STODDARD



## PHYSICAL PLANT

The main thrust of the department's effort during the year was in the area of operating efficiency and systems development. Progress is being realized in the continuing program to improve operating practices and procedures.

Continuing revision of operating techniques and reorganization of supervisory personnel in the building services group have helped minimize the impact of the escalating cost of labor and the increasing difficulty in recruiting personnel for entry-level positions. In order to meet the peaks of service demand associated with special events and to continue upgrading the services offered, increased emphasis will have to be placed on uncovering and utilizing improved materials and more effective techniques.

New construction activity was slightly lower than in prior years, reflecting a gradual leveling-off from the concentrated effort of the Second Century Fund period. The Camille Dreyfus Building for chemistry, the hydrodynamics addition, and MacGregor House were all delayed due to severe winter weather and to labor strikes connected with construction worker wage negotiations. Two major projects were substantially completed during the year, the Engineering Library renovation and rehabilitation and the Linear Accelerator in Middleton, Massachusetts. The latter will require at least another year for the installation by the Laboratory for Nuclear Science of the accelerator and other research equipment.

The Building Committee approved the preliminary design for the new Electrical Engineering and Communications Research Facility on Vassar Street and preparation of working drawings by the architect is under way. Gross floor area will be approximately 250,000 square feet, and the facility will include a 225-seat lecture hall. The current schedule calls for construction to start on this project early in 1970.

The Building Committee also approved preliminary layouts for a complete modernization of the Burton-Conner dormitory complex, with construction scheduled to begin in the summer of 1970. The building will be changed to a suite arrangement and the number of students housed reduced from 545 to about 350. When complete, this project will provide housing of a standard comparable to MacGregor House.

Preliminary design work was initiated on a 400-man graduate student apartment facility adjacent to the Westgate married student housing complex. This facility is intended to house single graduate students in one-, two-, three-, and four-bedroom apartments comparable to a conventional apartment building. A unique feature of the proposed design is the possibility of conversion at a later date to one- and two-bedroom housing for married students and faculty.

Over the years, two major renovations of the power plant facility have increased the steam generation capability by approximately 500 per cent. Relying on the experience gained, and looking forward to a continuing increase in the need for steam, we are giving due consideration to future expansion in designing the new steam plant. A modular approach is being used, and it is anticipated that optimizing the new facility will ultimately allow doubling our present capability using presently available technology.

The West Campus utilities expansion is an integrated program designed to yield a balanced and coordinated increase in our capability to service the steam, electricity, and communications needs of the West Campus development. The sizeable investment now being made, by recognizing the needs of all the major utilities simultaneously, will greatly reduce the ultimate cost of servicing this area.

Design work has started on Phase II of the Central Refrigeration Plant — an addition of a 3,500-ton refrigeration machine within the existing refrigeration plant structure, with associated cooling towers planned for a location north of the Central Utilities Plant just across the Penn Central railway line. Two-hundred-thousand-gallon oil storage capacity is being installed as a part of the cooling tower structure foundation. The planning accommodates a third refrigeration module in the central structure, with adequate cooling tower capacity.

Development of the telecommunications service function is gaining momentum. One aspect of this is the expanded application of the radio paging system, which allows for more effective use of supervisory personnel as well as a quicker reaction capability in responding to breakdown and emergency repair situations. Another and more far-reaching element of this is the expansion of the telephone and data switching systems. Increased application of computer technology to educational and research methodology is being supported by the centralization of order service and maintenance support for data console activities. An order has been placed with the telephone company for the new central switching system (CENTREX) to serve the telephone and data communication needs of all Cambridge activities.

A computer program was developed and successfully used in balancing the heating system in Eastgate; it is now being used in other applications, where it is proving to be a valuable design tool. In addition to the more obvious tangible advantages, the department was able to interact with students and provide meaningful on-the-job training and work experience by having student participation in the development program.

Recognition should be given to two staff members leaving the department during the year — Raymond S. Howell, retiring after 46 years in

#### **SAFETY OFFICE**

the building maintenance area, and Edward T. Pieper, construction manager for 17 years, who accepted a position with the National Gallery of Art.

**CARL M. F. PETERSON**

#### **SAFETY OFFICE**

Accidental injury and severity ratios continued to decline for the second straight year, with the loss rate indicating a substantial decrease compared to the previous year's figures.

The installation of automatic sprinkler systems, fire detection devices, and emergency lighting continues in Institute buildings, with emphasis placed on dormitories and other living units.

The entire main group is now equipped with modern fire alarm and watchman stations.

Raymond Diffley accepted a position as assistant safety engineer in this office on March 3, 1969.

**MARK J. DONDERO**

#### **CAMPUS PATROL**

Problems faced by the Campus Patrol have increased in complexity, number and size much more rapidly than the growth of the community itself. For example, in 1962 there were a total of 325 written complaints submitted to the Campus Patrol Office; in 1968 there were 806, an increase of 148 per cent for the five-year period. In just the last three years — 1966 through 1968 — ambulance service provided by the Campus Patrol jumped from 225 to 431 cases, an increase of 92 per cent. This does not include 237 other types of emergency service involving the Campus Patrol cruisers. Parking violations rose from 6,000 in 1966 to 9,500 in 1968, up 58 per cent. During the last year, on-campus thefts have risen sharply, following a national trend in this direction. Situations involving missing or disturbed persons have also shown a sharp increase, particularly putting parents in direct contact with students. In fact, the Institute faces all of the problems of misdemeanors, crime, accidents, disturbed persons, traffic control, and parking that face any normal city or town of 15,000 persons. It is becoming a major challenge to continue to provide for the safety, well-being, and convenience of our growing community in the manner which the community demands.

**ALBERT F. SISE**

### **GRAPHIC ARTS SERVICE**

During the last year, the Graphic Arts Service made several notable changes in operation. A major change was the adoption of the 5-3-2 pricing for Xerox prints (5 cents for the first copy, 3 cents for the second to tenth, and 2 cents for the eleventh and over). This reduction in prices could be maintained only if a substantial increase in volume was achieved. The M.I.T. community has fulfilled this requirement, and these low rates have been extended to our other branches located at Building E19-220 and Building E52-442.

The installation of new high-speed multilith, offset press and collating equipment has improved plant efficiency and added to our capabilities. The increased volume of work this equipment is capable of producing has made it possible for quicker delivery with improved quality at substantial savings in cost.

The volume of work has continued to increase throughout the year. The balance of the Graphic Arts Service functioned in a normal manner except for the Audio-Visual operations, which is still undergoing tremendous pressure from ever-increasing demands. This has necessitated considerable additional equipment and personnel. With this growth, the space requirements have become acute sooner than was anticipated a year ago. However, Jerome H. Adler and his associates have done a commendable job in the face of a shortage of help and a lack of proper space.

FRANK H. CONANT

### **HOUSING AND DINING SERVICES**

The start of construction of the Frank S. MacGregor House marked a significant step in the undergraduate housing program. Housing 324 undergraduate men, nine graduate tutors, and two faculty families, the complex will be a departure from traditional dormitory housing and an embodiment of the principles guiding the development of a new residential system as outlined in the Report of the Faculty Committee on Student Environment issued in 1963. The program will be supplemented further by the rehabilitation of Burton House upon completion of MacGregor House. Plans have been developed by a client group representing students, faculty, and administration.

Planning also proceeded on new graduate housing, with the announcement of a residential program to include apartment-style accommodations for 400 single graduate men and women on West Campus.

The rehabilitation of East Campus this summer was well received by

#### ENDICOTT HOUSE

the student community residing there and was enhanced by the addition of several floor lounges. These lounges also served to ease severe overcrowding in the fall, as more than 80 freshmen were placed into temporarily crowded rooms. This problem will continue until a second house is completed in 1972.

This year Kenneth C. Browning joined the Housing staff as assistant to the director of Housing and Dining Services. He has assumed major responsibility for all housing assignments and for organizing a decentralized assignment program serving student interests in each house. The support capability of the Housing office has been greatly increased by these programs.

LAURENCE H. BISHOFF

#### ENDICOTT HOUSE

Endicott House was used 277 days in 1967-68, including 241 nights by resident groups. Overnights total 5,294, an average of 22 guests a night for resident conferences.

A total of 88 nonresident groups used the house during the year. The number of meals served were 22,494, an average of 81 meals per day of operation. Nonresident guests from the M.I.T. community totaled 4,052.

Financially, the last year was most successful, allowing the completion of some deferred maintenance and refurbishing projects.

Miss Aimee Pierson, who has been at Endicott House for the last year and a half, has been appointed the new manager, succeeding Mrs. Elim O'Shaughnessy.

MARY O'SHAUGHNESSY



## **VICE PRESIDENT AND SECRETARY OF THE INSTITUTE**

**T**he past academic year has been called the year of the student. It was also a year in which our colleges and universities grew in strength and understanding. On many campuses it was a time of testing and of irreversible change. This was also true at M.I.T.

At one university the nation found that an appeal to reason and rationality was more than a slogan. That university was favored by a prior orientation to the mainstream of societal problems and to serious purpose among its students. It was also favored by gifted leadership. This was M.I.T.

The year was marked by the continued overshadowing of the financial threat to our great private universities by the problem of campus unrest. The headlines were largely dominated by current events, while the quiet struggle in the counting room continued unnoticed. Outside the glare of publicity, the losses in forward planning in order to cope with day-to-day operations may have been noticed in the inner councils of the Institute but hardly beyond.

Private gifts, grants, and bequests continued to grow, reaching nearly \$30 million in the aggregate — the Institute's second best year of private support in its history. M.I.T. stood among the top five universities in the nation in the volume of private support for the year.

In many ways the Institute grew in strength and skills as new priorities and new resources to meet new needs were brought into concrete form.

### **CORPORATION**

At the year's end there were 84 Members of the Corporation — 70 Active Members and 14 Life Members Emeriti. During the year, Eugene Mc-

Dermott, Director of Texas Instruments Incorporated, was elected a Life Member; Mervin J. Kelly transferred to Life Member Emeritus.

Among the important changes in membership occurring during the year, the Corporation elected its first European, a distinguished Negro educator, and the youngest Corporation Member in the history of the Institute. James A. Champy '63, an attorney from Lawrence, Massachusetts; Elisha Gray II '28, Chairman of the Board, Whirlpool Corporation; William R. Hawthorne '39, Master of Churchill College, University of Cambridge, England; Jerome H. Holland, President, Hampton Institute; Breene M. Kerr '51, Senior Partner, Resource Analysis and Management Group, Inc.; Carl M. Mueller '41, Partner, Loeb, Rhoades & Co.; Harold E. Thayer '34, Chairman and President, Mallinckrodt Chemical Works; and Jephtha H. Wade, Partner, Choate, Hall & Stewart were elected Members of the Corporation for five-year terms. Philip H. Peters '37, Senior Vice President, John Hancock Mutual Life Insurance Company, became an *ex officio* Member of the Corporation by virtue of his election as the 1969-70 President of the Alumni Association.

Expiration of membership has cost the Corporation the formal associations of Emilio G. Collado, Executive Vice President, Standard Oil Company (New Jersey); M. Wren Gabel, former Executive Vice President, Eastman Kodak Company; Ivan A. Getting, President, Aerospace Corporation; and Samuel A. Groves, Former Chairman and President, United-Carr Corporation.

Two new Representatives of the Commonwealth of Massachusetts became Members of the Corporation: Francis W. Sargent '39 succeeded John A. Volpe as Governor of the Commonwealth, and Neil V. Sullivan succeeded Owen B. Kiernan as Commissioner of Education.

#### REVISION OF BYLAWS

The Ad Hoc Committee on the Structure of the Corporation, chaired by Life Member Marshall B. Dalton, completed its report, and the Corporation voted to accept the Committee's recommended changes at its Annual Meeting of October 4, 1968. Under the revised Bylaws, the number of Life Members is limited to 25 persons elected since July 1, 1960. The previous limit of 35 Life Members was abolished. The previous categories of Special Term and Alumni Term Members were abolished in favor of a single category of Members who are elected for five years and are eligible for re-election for a second five-year period. The number of Members is limited to a maximum of 15 Members nominated by the Alumni Association and 25 Members chosen by the Membership Committee. A further limitation in the total number of Members is that their number, when



added to the total of Life Members elected since July 1, 1960, shall not exceed 50 at any one time.

A further significant change in the Bylaws provides for the continuing service of Emeritus Life Members on all Committees of the Corporation.

THE CORPORATION JOINT ADVISORY COMMITTEE  
ON INSTITUTE-WIDE AFFAIRS

At its meeting on March 7, 1969, the Corporation of M.I.T. voted to establish a new special committee to be called the Corporation Joint Advisory Committee on Institute-Wide Affairs. The membership of this new committee includes students, faculty members, and Corporation Members. Its purpose is to associate with the Corporation a broadly representative group at the Institute to which the Corporation can turn for consideration and advice on special Institute-wide matters, such as the long-range planning of our campus, the improvement of our institutional environment, and M.I.T.'s relations with Cambridge and Metropolitan Boston. In considering such matters, the Joint Committee will make available to the Corporation information, views, and advice resulting especially from discussion and interaction among students, faculty members, and Corporation Members meeting together.

The Corporation hopes that the committee will provide an additional means for bringing representatives of the student body, both graduate and undergraduate, and representatives of the faculty into regular communication with the Corporation on matters not normally handled by the faculty and which are of long-range importance to the entire Institute community. The Joint Committee can also serve to acquaint the M.I.T. community more fully concerning the role and work of the Corporation.

As it has from the founding of the Institute, the Corporation will continue to look to the faculty or faculty committees for the conduct of the Institute's educational program and related responsibilities and for recommendations to the Corporation on academic matters requiring Corporation action.

The new committee will not in any way modify the role of the existing Corporation Visiting Committees. They will continue to conduct their affairs in the same manner as they have in the past. For example, the role of the Visiting Committee on Student Affairs will be unchanged, and it will continue its primary interest in student life and student welfare.

The Joint Committee, the members of which will be formally appointed by the Corporation, will consist of the following membership:

Six Members of the Corporation (one of whom will be Chairman of the Joint Committee). Of these six, who will be nominated by the Corporation Membership

#### VICE PRESIDENT AND SECRETARY

Committee, one will be the President of the Alumni Association, and at least one will have special interests and background relating to the Boston and Cambridge communities.

Six members of the faculty nominated by the faculty, one of whom would be the Chairman of the Faculty.

Six students, which number would include the President of the Undergraduate Association, the Chairman of the Graduate Student Council, plus two undergraduate students nominated by an elective process by undergraduates and two graduate students nominated by an elective process by graduate students.

On behalf of the Joint Committee, its chairman will be expected to make periodic reports to the Corporation on the deliberations of the committee.

The Joint Committee is constituted as a committee of annual recurrence under the Bylaws of the Corporation. Membership in the Joint Committee other than students will be for a term of three years. Students will be nominated each year for one-year terms and to complete unexpired terms, and they may be nominated for additional terms. Where faculty or students serve in the capacity of the office they hold (Chairman of the Faculty, Chairman of the Graduate Student Council, and President of the Undergraduate Association), their service on the committee will be concurrent with their service in the offices they hold.

The term of service of the new committee, along with other Corporation committees, will begin with the Annual Meeting of the Corporation in October, 1969.

#### CORPORATION VISITING COMMITTEES

The past year has represented a significant milestone in the history of the Corporation Visiting Committees at M.I.T. As presently structured, these Committees have been serving the Institute for 40 years. Founded in 1929, their impact on the growth, the change, and the vitality of M.I.T. has been most impressive. During the past 40 years, 35 Visiting Committees have existed; 19 of the present 26 Committees have had continuous service during this period. To date, 1,240 individuals have served on one or more of the Committees.

Throughout this 40-year period, the Committees provided advice and consent which is actively sought by the various departments. As the widespread effects of the Institute's progress have developed, the Visiting Committees, through their sound interaction with the Institute's departments, have established a strong tradition. In this, their fortieth year at M.I.T., the Committees have brought to bear the dynamic and refreshing approach to issues that is so often not only helpful but also mandatory

in the light of continued growth and change of the Institute and the society which it ultimately serves.

During 1968-69, the Visiting Committee program continued to gain widespread acceptance by both the faculty and students at the Institute. Attendance at meetings by the major administrative officers was consistently high, and their participation in the discussions was most welcome. This year student participation in the work of the Committees has been greatly enlarged.

As a focal point for Corporation, administration, alumni, and professional interest, the Visiting Committee program was clearly significant in departmental affairs. That the Visiting Committee can increasingly serve as a unifying Institute element will add to the future importance of its role.

The input of student participation at the meetings was initiated as a general policy this year. All Committees met in open or executive session with both graduate and undergraduate students from the respective departments. The sessions were active and helpful, based on the reactions of faculty, students, and Committee members. The dialogue thus enhanced should be continued as an additional arena for discussion of policy, as well as a vehicle for sincere student interest in furthering the aims of quality education and basic research at M.I.T.

Administratively, too, the program appeared to operate at a smooth and effective level. No small part of this effectiveness is due again to the rising interest in the Committees within the M.I.T. community.

#### MEMBERSHIP

In 1968-69, 211 individuals served on one or more of the Visiting Committees. They included 49 Members of the Corporation, 82 Members nominated by the President, and 80 Members nominated by the Alumni Association.

The Corporation Members who served averaged 1.7 Committee assignments per Member and had an average of 3.2 years of service on the particular Committee. The Presidential and Alumni Association nominees, each serving on one Committee, had an average of service of 2.5 and 2.2 years respectively.

#### MEETINGS

During the past academic year, 12 Committees held meetings. One Committee, due to the complexity of the issues which were being discussed, held two meetings in the spring. This number of meetings is in contrast to the 1967-68 schedule when 24 of the 26 Committees met.

The schedule, however, does appear to be molding into the suggested pattern of 16-18 meetings per year, as submitted last year, which would

necessitate some Committees meeting annually and others meeting once every 18 months. At present, only one Committee (Mathematics) is experiencing a lapse of two years between meetings.

Paul E. Johnson continued to provide superb administrative support to the Visiting Committee program, including the scheduling and arrangements of meetings, sending relevant information to Committee members during the year, and processing reports of the Committee meetings. Communications with individual Committee members about activities and developments at the Institute continued to be a major office responsibility.

The picture book of Visiting Committees and their members, which was published initially in 1967-68, was produced again this year. The booklet, distributed in the fall, continued to fill a key communication link between committee members and Institute personnel.

#### DEVELOPMENT

Two years ago President Johnson announced a capital projection of \$135 million by 1975 over and above private gifts and grants needed for annual operating purposes. In order to achieve this overall goal, he called for a minimum level of annual gifts, grants, and bequests totaling at least \$30 million per year.

During the past two years, we have made notable progress towards these goals. The second and third best gift years in M.I.T.'s history were 1968-69 and 1967-68. Within the framework of the development program, the Institute Secretaries, D. Hugh Darden, C. Warren Smalzel, David J. Tobin, Paul H. Burr, and their respective offices continued to make important progress in developing improved communications with donors and prospective donors among private individuals, corporations, charitable trusts, and foundations. In addition, these development officers, working in close coordination with Nelson C. Lees, Director of the Development Office, made major improvements in relating the work of the development staff to the ongoing needs of the departments and laboratories for operating funds. As their work has grown in volume and effectiveness, individual members of the faculty find it increasingly profitable to turn to the Institute Secretaries and to the Development Office for advice and assistance in soliciting private support. At midyear, John H. Carter, Institute Secretary, resigned to devote full time to a growth company which he founded.

The reports of the directors of the Industrial Liaison Office, M.I.T. Associates Office, Development Office, and Registry of Guests follow.

VINCENT A. FULMER

## INDUSTRIAL LIAISON OFFICE

The history and growth of the Industrial Liaison Program at M.I.T. now spans two decades. The Institute has pioneered this form of organization for the efficient transfer and exchange of technology between universities and industry. Although our Program has served as a model for over fifty programs of this type sponsored by the nation's major universities, the M.I.T. Industrial Liaison Program continues to maintain a leadership role.

Located within the administrative structure of the Institute, the Liaison Office seeks to provide an effective channel both for communicating the results of M.I.T.'s research and educational programs to industry and also for bringing information on industrial and business activities to the attention of the M.I.T. community. Several mechanisms have been established to carry out that purpose. Principal among these are: (1) the distribution of M.I.T.'s technical reports to industry and the distribution of appropriate company-generated technical reports at the Institute; (2) a continuing series of symposia which broadly reflect the Institute's research; (3) provision for visits to M.I.T. by members of company technical and management staff; (4) sponsorship of faculty, and on occasion student, visits to the laboratories of industrial firms to explore areas of mutual interest; (5) assignment of an Industrial Liaison Officer who maintains a knowledge both of M.I.T.'s activities and of the company's interests and works to bring those interests together wherever possible. Consulting and sponsored research are not a formal part of the Industrial Liaison Program, but the close working association which develops often leads quite naturally to direct relationships of that nature. The office assists in the establishment of consulting and sponsored research when requested by the company.

This combination of routine services and personalized attention by a Liaison Officer responsible for stimulating interchange between individuals working in areas of mutual concern provides the fundamental mechanics of the Program. Quite often, however, the Liaison Office serves only as the initiating point for what later develops into long-standing and significant professional associations. We view this as an appropriate role and do not attempt to exert control over the interaction after it has been demonstrated to be of mutual benefit to M.I.T. and to the industrial firm.

At the close of the fiscal year, there were 105 companies participating in the Liaison Program. Distribution of those companies among major industrial groups was as follows:

Aerospace	20%
Automotive	5

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Chemical	15
Electronics	23
Food	2
Insurance	2
Manufacturing	10
Metals	9
Paper	1
Petroleum	9
Other	4

The value which industry places on its close association with M.I.T. is perhaps best demonstrated by the record of renewed memberships in the Liaison Program. Thirty-nine of the present member companies have been continuous participants for the last fifteen years. Over 60 companies have now reached their tenth year.

Again this year we have sponsored 18 symposia in order to provide timely indepth reports on Institute research programs of special import to the member companies. Total attendance this year reached 2,237. The number of company representatives at those programs increased over last year to a total of 1,835. The remaining attendance was accounted for by representatives of the M.I.T. community and by special guests, including sponsors of the research being reported. One hundred thirty-one of the Institute's faculty and staff presented the results of their research and exchanged ideas with the audience during those meetings. Subjects discussed are selected on the basis of their application to industrial use and the amount of new and often previously unreported information available for presentation. The Industrial Liaison Office also feels a responsibility to draw attention to the entire spectrum of the Institute's research. In accord with this, the success of each meeting is judged more on the basis of the qualifications of those who participate and the significance of the discussions which evolve, rather than solely on the number who attend.

The following symposia were presented during the year: Metabolic Adaptation to Environment, Field-Effect Transistors, Heat Transfer, Management Information and Control Systems, Display Technology, Rock Mechanics, Lasers in Physics Research, Processing of Metallic and Ceramic Materials, Deep Submergence Vehicles (Los Angeles), Libraries and Information Resources, New Spectroscopic Methods in Chemical Research, Management of Human Resources (Los Angeles), Computer-Aided LSI Design, Interactive Computer Systems, Optical Communication Systems, Physical System Simulation, Urban Systems, and Operations Research for Public Systems.

Personal contact between faculty and representatives of the member companies for the purpose of discussing areas of mutual concern, either of a long-range nature or of immediate application, is one of the most significant features of the Industrial Liaison Program service. These visits arise in a number of ways. They may come about as a result of the company's review of technical reports on various projects at the Institute and its wish for further up-to-the-minute information on those studies or to explore the specific application of that work to the company's own research and engineering activities. They may come about as a direct request on the part of the company, either to talk with a specific faculty member or to explore a given subject area. They often arise out of the individual Liaison Officer's initiative in bringing people together to discuss activities of mutual interest. During the past year, 287 campus visits were arranged through the Industrial Liaison Office. A total of 374 faculty and staff took part in discussions with company representatives during 633 separate appointments. A total of 537 key individuals represented 74 member companies during those meetings.

Industrial firms especially welcome visits to their facilities by representatives of the Institute and, guided by the criteria of mutual professional benefit, this facet of the program will be continually strengthened. The Industrial Liaison Office encourages members of the faculty to visit company research laboratories, schedules appointments, provides introductions, background information and sponsorship, and generally ensures the effective use of the individual's time. Such visits may involve a seminar and informal discussions, as well as a personal review of company research and development programs which relate to the visitor's own professional interests. A modest amount of student participation in visits to companies has been conducted to date and has proven a particularly worthwhile experience which provides a firsthand view of industrial research, engineering, and management practices. Sixty-nine visits by faculty members to companies under auspices of the Industrial Liaison Office were recorded during the year.

Each year the Industrial Liaison Office compiles and publishes a complete listing of research underway at the Institute under the title *Directory of Current Research*. For internal convenience, the 1969 edition of the Directory was modified slightly in the method used to number and account for projects which currently total 1,443. It is intended to serve as a reference source both for representatives of companies and for the Institute community and furnishes a convenient means of attaining access to specific research activities. More than 3,400 copies of the Directory were distributed directly to participating companies this year. In addition, 1,400 copies were provided to faculty, staff, and students

and an additional 665 copies were personally distributed to company representatives by the Industrial Liaison Officers. The Liaison Office maintains and updates the file of publications generated by each project.

The Liaison Publications Office automatically forwards copies of the Institute's technical reports on subjects known to be of direct interest to various divisions and laboratories of firms. During the past year, more than 170,000 documents representing 349 separate preprints and laboratory reports were distributed to 716 different company locations. An additional 214 other reports were made available on request. A *Monthly List of Publications* is compiled and published, and copies were sent regularly to 690 key individuals in industrial research organizations, and that service resulted in further requests for Institute publications. An additional 44 individuals within M.I.T. regularly receive and use the *MLOP*. The Publications Office responded to some 4,000 individual requests from companies for technical reports. Requests for reports received from members of the M.I.T. community and requests answered personally by the Industrial Liaison Officers accounted for an additional 500 responses. Some time ago we instituted a service of automatically notifying individuals of further publications generated by projects in which they had expressed interest. Notices of that kind involved approximately 600 communications during the past year. Increasingly good response is being received to the Liaison Office's practice of forwarding company technical reports to appropriate members of the faculty. Nine hundred and seven reports of this type were received during the year, most of which have been forwarded directly to the faculty having a special interest in their content. Access to the M.I.T. library system is especially useful to member companies in the local area, and the libraries have cooperated in making 672 library privilege cards available to representatives of our companies.

During the year, Leslie M. Boring, Peter C. Farrell, Karl B. Kehler, Harry C. Moser, Carl H. Neu, Jr., Ronald S. Stone, and George W. Ullrich served as Industrial Liaison Officers. At year's end, Mr. J. Peter Bartl joined the staff to replace Mr. Kehler, who has completed his appointment and accepted a position in industry. I am pleased to report that Mr. Stone has agreed to remain on the staff of the Liaison Office an additional year as Assistant Director. I would like to express my appreciation to these men, whose initiative and enthusiasm stimulates the Program, and to the many members of M.I.T.'s faculty, administration, and staff whose generous effort has made the Program valuable both to industry and to M.I.T.

JACK W. CHRISTENSEN



## **M.I.T. ASSOCIATES PROGRAM**

The M.I.T. Associates Program, now in its ninth year of operation, has grown from its original charter membership of two companies to the present 31 firms. The wide variation in the types of industries represented in the membership is a reflection not only of the flexibility of the services provided through the Associates Office, but also of the broad range of activities at the Institute which are of interest to them. Represented in the Associates membership are banking, insurance, educational products, machine tool, aerospace, commercial electronics, apparel, electrical, utility, construction, and computer software firms.

The purpose of the M.I.T. Associates Program is to foster a working relationship between the participating members and the Institute community. Its aim is to ensure that the companies are informed on a timely basis of ongoing projects and new developments which have a direct influence on their own technological interests.

The services provided to the Program members include a number of major privileges, which are designed to give the companies convenient access to all of M.I.T.'s educational and research activities on campus, as well as to the two special laboratories. One of these is the selective distribution of progress reports, research reports, working papers, preprints, and theses. These papers are selected from over 1,400 research projects currently underway, and sent to the members on a regular basis, based on the Associates Office knowledge of the companies' interests. To further stimulate the interaction between companies and the faculty and staff of the Institute, the Associates Office mails out notices of seminars, colloquia, and other meetings. One of the most popular services is the personal visitations set up for company members with the faculty. These visits can be for any number of reasons, ranging from exploring the possibility of a consulting arrangement to an informal comparison of their respective research work. Some companies find that the full library privileges offered are most valuable to them, including the privilege of borrowing through the mails. Other types of assistance can also be obtained through the Associates Office, such as a personal contact with the faculty and staff for student recruiting, obtaining offhand reactions from the faculty on new products lines, or suggesting ideas and working together on student projects.

Several new areas of service were introduced over the past year and have worked out quite successfully. Four courtesy visits by M.I.T. faculty members were made to companies this year. The typical format of these visits included an informal discussion by the faculty member of his research with a group of technical people from the company, a plant tour, and individual discussions. In a similar vein, luncheon meetings at

the Faculty Club have been expanded for the companies in which a faculty member will discuss his activities informally with a group of management or top technical people from the member companies. A third service which was implemented this year on a trial basis was an advance seminar notice system. As soon as a seminar is announced, a particular company interested in that series will receive a notice. This new service has been particularly well received.

Activity levels and use of the Program services increased this year due both to the additional membership and to increased interest on the part of the companies. In fact, one company was so active that they were asked to increase their level of support and readily complied with the request. Sixty-six representatives from the member firms visited a total of 64 faculty and staff. Over 1,200 publications were selected and mailed to the companies. An entirely new interest area seems to be appearing, that of the responsiveness on the part of industry to student activities and student opinion. The first report of the Review Panel on Special Laboratories, which was written by both faculty and students, was sent out to the companies, and considerable interest was shown in response.

The Conference for New England Executives this year was the largest ever held, having an attendance of 184 guests. Invitations were extended to 1,141 chairmen and presidents of leading New England firms.

The topic was "Electrical Science and Engineering: New Prospects for Corporate Growth." President Johnson opened the meeting with a warm welcome to the guests, and Dean Gordon S. Brown chaired the afternoon session. Professor J. C. R. Licklider discussed the growth of Project MAC at M.I.T. and suggested some new directions for its future. Professor Herbert H. Woodson addressed himself to utility system reliability and used as one example the major blackout in the Northeast in 1965. Professor Harry C. Gatos explored several new breakthroughs in electronic materials, and Professor Samuel J. Mason discussed new information processing techniques in the context of his reading machine research. A reception was held at President Johnson's house for the guests, followed by dinner at the M.I.T. Faculty Club. After dinner Dr. Henry E. Singleton, Chairman of the Board and Chief Executive Officer of Tele-dyne, Incorporated, provided enjoyable and thought-provoking remarks about some of the important developments at M.I.T. that have had great influence on the nation's industry. Dr. Jerome B. Wiesner discussed important new directions for M.I.T. in educational research and urban affairs.

In conclusion, I would like to extend to the faculty and staff who have participated in Associates Program activities my sincerest thanks for the generous giving of their time and effort. I speak on behalf of the member

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companies as well as the Associates Office when I say that this cooperative spirit makes possible the success of the M.I.T. Associates Program.

DAVID H. ROBBINS

DEVELOPMENT OFFICE

The cash flow of private gifts, grants, and bequests to M.I.T. for the year was \$29,652,080, a three-year high and the second highest year in the history of M.I.T. Sources of gifts were the following:

Alumni and Alumni Clubs	\$12,241,881
Non-Alumni Friends	3,139,379
Corporations, Corporate Foundations and Trade Associations	5,830,544
Foundations and Charitable Trusts	8,397,427
Others	42,848

As expected, gifts attributable to the Second Century Fund continued to decline. The maintenance of an average level of gift income well in excess of \$25 million during the past five years indicates that to date the Institute has been successful in attracting substantial levels of support in the absence of a major capital campaign.

Two projects of particular note during the past year in which this office has been involved were the funding of the Warren K. Lewis Professorship of Chemical Engineering, which totalled over \$650,000 by the end of this fiscal year, and the continuing campaign to fund the new Electrical Engineering and Electronics Complex for which a total of \$15 million is sought and towards which \$9,000,000 has so far been raised.

I have given considerable attention during the year to resources and procedures in the Development Office. A modest program for computer analysis of gift income data has been proposed to supplement the existing and excellent gift record system of the Treasurer's Office, in order to evaluate specific key components in the Institute's development program and to indicate specific donor sectors where additional effort may be appropriate.

We have redesigned Development Office records, including our basic means for communicating donor information to the development staff, for individuals and corporations. We have evaluated a wide variety of additional information sources, especially relating to individuals and corporations, and as a result have been able to expand substantially our data bank on current and potential donors. Two tasks now before us are to cross-relate this information more closely and to use it more actively so that we can generate specific recommendations effectively

and routinely for evaluation and action by members of the development staff. During the year, we have also reorganized some of the staff responsibilities within the Development Office.

These activities are part of a long-range program to build a marketing approach to the development process commensurate with this office's increasing ability to process and evaluate information, with the increasing sophistication of donors, and with the increasing needs of the Institute.

Four circumstances are currently affecting — and will continue to affect — private support of higher education: tax proposals now under consideration which may substantially alter patterns of giving, particularly by individuals and foundations; changes in the national economy resulting from continuing and rapid inflation; substantial cutbacks in many areas of federal support of higher education; and the varying responses to national campus unrest. These create a sobering climate in which we shall be carrying ahead the Institute's ongoing development program in the year ahead.

In personnel notes, Lew F. Boyd joined this office in August as Assistant to the Director. I regretfully record that he will be leaving shortly after the end of the fiscal year to accept a position at the Harvard Medical School. I am happy to report that James W. Lambert, Director of Planning at the University of Southern California School of Engineering, has accepted an appointment as Assistant Director of the Development Office and will be joining the staff next August.

NELSON C. LEES

### **OFFICE OF THE REGISTRY OF GUESTS**

The Registry has just completed the busiest year in its history. This is not actually revealed in the number of visitors scheduled, which totals 844 or about 200 more than in 1967-1968. However, the visitors this year have in many cases required quite detailed programs. In addition, this office rendered more assistance than usual to the special category of Eisenhower Exchange Fellow, particularly in correlating such visits with other universities and businesses in this area. The Registry also helped to a limited extent in arranging home hospitality or sightseeing for the wives of the Eisenhower Fellows, especially in conjunction with the M.I.T. Matrons.

The 844 foreign visitors represent 62 foreign countries. The greatest number came from Japan, and again this year the Sloan School of Management received the largest number of foreign visitors. There were, of

REGISTRY OF GUESTS

course, many visitors attending conferences at the Institute who are not included in these totals.

As of November, 1968, there were 429 foreign staff and faculty appointed to the Institute, a reduction from 1967-1968, as shown in the following tabulation:

	1959-1960	1967-1968	1968-1969
Guests	28	12	8
Administration	0	6	7
Teaching	24	143	134
Research	131	315	280
<b>Total</b>	<b>183</b>	<b>476</b>	<b>429</b>

As in 1967-1968, the largest proportion was British. In all, 54 countries were represented by these foreign staff members.

The Registry assisted the Committee on Commencement, as in the past, and also during 1968-1969 secured 57 delegates to represent M.I.T. at a variety of academic functions at other universities.

CAROLYN B. COX



## VICE PRESIDENT, ORGANIZATION SYSTEMS

**T**his has been an eventful year at M.I.T., a year of introspection and change, foreshadowing perhaps greater changes to come as the Institute examines its goals and purposes and means for achieving them.

No segment of the Institute can escape the demand to test its organization, values, policies, and methods against the larger needs and purposes of the Institute. The emphasis of this report will be on efforts during the past year to create a more effective structure to carry out the responsibilities within my scope as Vice President, Organization Systems.

These responsibilities include coordination of planning for the physical facilities of the campus, stimulating improvement in systems for administrative operations, maintaining a capability for developing such systems, and providing assistance in the analysis of alternative policies, organizational forms, and resource uses.

The following reports of the M.I.T. Planning Office and the Office of Institutional Studies, recently renamed Office of Administrative Systems, outline their principal activities during the year. They record, in the case of the Planning Office, a substantial output in long-term planning for new facilities, in the programming of new buildings and building renovations, and in the re-allocation of existing space to meet changing needs. In the case of the Office of Administrative Systems, the report reflects a steady output and continuing refinement in computer-based records and reports for M.I.T. administrative offices.

What is not so visible in these reports is the energy devoted to improvement in the structure and staffing for carrying on these substantial responsibilities. A long-range planning group has been created within the Planning Office to work closely with academic and administrative

departments. The group is defining future facility needs and planning the means by which they can best be met through a combination of our existing inventory of space and new construction. The building program and design review group has been strengthened and the data base serving it refined to permit a more prompt response to departmental needs. The Planning Office has assumed and has been staffed to meet the responsibility for a coordinated planning of the design of the internal environment of the Institute, including the corridors and public spaces. The planning systems group has continued to develop the process and data base for monitoring the Institute's space inventory and utilization and has devised better internal procedures for scheduling and controlling the work of the Planning Office itself.

The responsibilities of the Office of Administrative Systems have been more clearly defined and organized. That office has never been adequately manned for institutional studies. Its primary work has been to devise and improve computer-based systems for the administrative offices, other than those engaged in financial administration, and to operate an administrative data processing service. The office has now been relieved of any responsibility for special analyses or studies. Its focus is on improvement in the Institute's administrative information system. This includes a continuous refinement of existing work for its client offices and the designing of new components of the Institute information system. The principal effort of the past year, in collaboration with the Office of Personnel Relations and the Faculty Records Office, has been the study of a computer-based system for the data processing needs of those offices and for the flow of personnel information throughout the campus. When completed, this record, together with the Comptroller's financial data bank and the space inventory of the Planning Office, will form the primary resource files of the M.I.T. information system.

Responsibility for special studies will be assigned to a newly formed office named the Analytical Studies Group, which will begin work in July, 1969. Assistance in the organization of this office was provided by the Ford Foundation through a three-year grant to support the professional staff membership. The services of the Group are intended to be available to the President, the Provost, the Academic Council and others at the Institute. Their special competence is in systems design and analysis. They are expected to be available and to assist in the study of proposed new administrative policies or organization forms and in the analysis of alternative proposals for use of the Institute's resources.

Lest the emphasis in this report imply more concern with process and organization than with substance and content, let me say only that it reflects an early period in the organization and development of a capa-



bility to meet my responsibilities as Vice President, Organization Systems. The work of building an organization is not finished, but the principal elements are in place, and I am hopeful their future work will verify the strength of their structure.

JOHN M. WYNNE

## OFFICE OF INSTITUTIONAL STUDIES

### OFFICE OPERATIONS

During the 1969 fiscal year the Office of Institutional Studies (O.I.S.) provided administrative data processing services to 27 offices, including the following six offices, which used these services for the first time: Committees of the Faculty (2), Faculty Records Office, Industrial Liaison Office, The M.I.T. Press, Office of Personnel Relations, and Real Estate Office. A complete list of client offices, including a brief description of services rendered, is attached as an exhibit to this report. During the last two fiscal years, there has been a net increase of 13 client offices served, nearly doubling the number included in my report to the President for fiscal 1967.

The decision to charge for services rendered by the office was fully implemented in 1969. This has the result of associating the cost of computer systems with the initiating agency. In addition, a process of review of proposed systems has been initiated to ascertain if the investment required provides an appropriate return to the Institute in terms of efficiency or effectiveness of operations.

### THE DEVELOPING ROLE OF THE OFFICE

The Office of Institutional Studies was initiated by the Registrar's Office in 1960 to solve the particular problems it faced in maintaining large student files and in manipulating subject schedules. During the next several years, the work of the office broadened, but remained predominantly in the student and alumni records area. While these systems are still maintained and periodically revised and strengthened, the primary thrust of the office in the last few years has been in areas of operation not directly related to students or alumni, as reflected by the expanding client-office list. This broadening of operating responsibility was recognized in 1967 when the responsibility for O.I.S. operations was transferred from the Vice President, Academic Administration, to the Vice President, Organization Systems.

It seems clear that this direction will be continued in the future. Although it is always difficult to project accurately, the challenges which

**Table I Client Offices of the Office of Institutional Studies — 1968-69**

Client Office	General Nature of Project
Admissions Office	Broad-scale file and output system; major system revision
Alumni Office	Broad-scale file and output system
Development Office	Deferred gifts historical file; system expansion study
Division of Sponsored Research	Computer time and operating system only
Educational Council	Broad-scale file and output system
Faculty Committee on Admissions and Student Aid	Special studies
*Faculty Nominations Committee	Questionnaire preparation and analysis
*Faculty Records Office	Systems feasibility study
*Industrial Liaison Office	New systems design and implementation
Department of Mathematics	Academic class lists
Medical Department	New systems design
*The M.I.T. Press	Tape file processing
*Personnel Relations	Systems feasibility study
Physical Plant	Computer time and operating system only
Placement Office — Alumni	Job application listing
Planning Office	Computer time and operating system only
Purchasing Office	Systems feasibility study
*Real Estate Office	Systems feasibility study
Registrar	Broad-scale file and output system; major systems revision
Office of Student Affairs and Freshman Advisory Council	Entering student information from General Student File
Student Aid Center	Broad-scale file and output systems; major system revision
Student Personnel	Student earnings analysis
Summer Session Office	Prospective registrant mailing lists
<i>The Tech</i>	Advertising billing system
Undergraduate Studies	Special studies
Vice President, Operations	Special studies

\*New Client-Office during fiscal year 1968-69

O.I.S. faces for the future can be identified as falling within the following three areas:

1. The first objective is to establish a mode of operations which provides a systems management capability which can be called upon by the entire M.I.T. community. This is a natural extension of current operations and reflects the existing expansion of systems services rendered in the last few years.

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For the future, means must be found to evaluate the efficacy of proposed systems adequately within the M.I.T. operating environment, in addition to the traditional role of the office, which has been that of designing and operating technically competent systems. In doing so, O.I.S. hopes to maintain a flexible service, which can be oriented to the needs of the individual user, without requiring professional systems competence resident in each client office.

2. The interest of the Institute in linking individual operational information systems to form an integrated information system to serve more efficiently the broader needs of the Institute as a whole was reported in the last President's Report. This effort has proceeded through the conceptual design stage and is currently being implemented on a phased basis, with each element of the system subject to review on a cost-justification and feasibility-study basis.

The bulk of such a system will remain under the control of the individual offices who have operating responsibility in the areas concerned, but there remains the necessity for interrelating the several systems to avoid duplication and to ensure complete coverage. This role constitutes the second objective over the long term.

3. The existence of an internal systems service office has substantial advantages to the Institute, since familiarity with the peculiarities of academic administration is helpful in establishing meaningful information systems. However, the very real cost of such computerized systems requires that the decision to implement, as well as the process of implementation, be handled as an "arm's length" business transaction.

There have been many changes in internal O.I.S. operations during the last year in this direction; examples of such a "client-office" relationship include: the charging system, the "contracts" with maximum upset prices for systems development, and the formal review stages inherent in all development work. Yet, it would be unrealistic to assume that this pattern of development has been completed.

The objective is to provide M.I.T. with an administrative computer systems service which is fully competitive with outside services, and at lower cost, while at the same time exhibiting more knowledge and sensitivity to internal operations than any outside service could claim.

DEAN L. JACOBY

## PLANNING OFFICE

This has been a year to remember. Filled with an incredible intensity, every aspect of the Institute's past, present, and future has been discussed and debated in some forum. The Institute's policies with respect to

growth, old and new academic programs, housing, environment, physical expansion, and community relations have had prominent places on the year's agenda. The staff of the Planning Office has been deeply involved in many of these issues, while in others it awaits policy direction that will hopefully result from ongoing deliberations.

Our greatest concern this year, as well as in the future, will be to insure that planning services are provided where and when they are needed. To this end, we have had under development a long-range planning framework that will permit us to estimate, more closely, the Institute's primary and related planning needs each year, for the next 15 years. We expect that, while the character of development may change, our community will continue to maintain an energetic pace of physical development. This year 18 different capital and major renovation projects were in process. They ranged from landscape improvements to major new buildings. The changing needs of our community, as reflected in the space change program, are equally dramatic. Eighty projects were under way during the year. While this level of activity may not be maintained indefinitely, it represents major efforts to upgrade the capabilities of areas long neglected, respond to the needs of new activities at the Institute, and facilitate the frequent physical adjustments needed by the academic and research community in the fulfillment of its tasks.

In Cambridge this year, our concerns were focused on housing problems for low-income and elderly families. These problems were brought to light in the dramatic form of a housing convention which met twice during the year and whose committees met frequently with various government, community, and university groups through the year. The Planning staff, with others, devoted uncounted hours to community meetings and to the completion of a housing development program that could respond effectively to the need — more important, a program that clearly involved participation from all sectors of the community.

Much of our ability to respond to planning needs is dependent on the quality and availability of information. We have made significant strides in developing and maintaining a system for data on the Institute's physical plant. This year the system enabled M.I.T. to submit automatically the first complete response to the Massachusetts Higher Education Facilities Inventory project. We are, in addition, pursuing the development of systems and programs that will assist us in planning capital expenditures, the building programming process, and the coordination of all planning activities with other Institute and community needs.

Finally, there has been much discussion during the past year regarding the functioning of the Institute's academic and administrative departments. There is a desire to know what has happened in the past, what

is under way, and what is to come. In an effort to share some of M.I.T.'s exciting past and the current activities of the Planning Office, we presented this spring a report to the community that illustrated the physical development of the Institute from its beginnings in Boston to projected developments for the next few years. We hope to share this with each entering class, and we plan to bring an up-to-date visual report to the community at the end of each year.

The following report describes the general scope of activities undertaken by each of the Planning Office's groups during the past year.

#### LONG-RANGE PLANNING

The long-range planning group is responsible for developing and maintaining a 15-year perspective on the physical and financial requirements necessary to accommodate the educational, environmental, and community objectives of M.I.T. These objectives are refined from information provided by academic departments on their aspirations for future growth and development. The long-range planning group specifies alternative types, sizes, arrangements, and locations of facilities that achieve the objectives, and reviews these alternatives with the members of the community affected. In order to assist the Institute in identifying and coordinating its long-term financial needs, the group maintains a comprehensive capital development and improvement program for the planning period. The program is continuously updated and refined through appropriate planning and design studies.

In general, the long-range physical development plan of the Institute is dynamic in nature, and the policies that comprise it are based in large measure on three kinds of studies undertaken by the long-range planning group: area planning studies, environmental systems studies, and studies aimed at developing new planning criteria for all types of Institute facilities. During the past year the group has been active in each of the above. Area planning studies for East Campus and for the Sloan Campus were initiated early in the year, and similar studies were begun recently for the West Campus. Both the indoor and outdoor environments of M.I.T. have been undergoing systematic analysis for the past year, with Planning Office staff, other members of the Institute community, and professional consultants participating. Alternative proposals on landscaping, signs, lighting, and related components of the environment are now being prepared, based on the analyses and conceptual studies developed this year.

It has been our hope for some time now to develop the essential criteria for an M.I.T. building system that could relieve the Institute of the limitations of specialized building design and could afford significant

economies in the construction of new space. This would represent another step in the group's effort to identify and analyze long-range needs in academic and research facilities at M.I.T., and to develop new criteria for the planning of these facilities. Special studies directed at identifying building construction systems that are flexible enough to meet changing future needs without sacrificing quality in design or in function were initiated during the past year and will continue as a special research project.

As for the development of facilities-planning criteria, a report describing future needs and preferences in graduate student housing is nearing completion. This report represents the second in the series of residential facilities studies that was begun several years ago with a similar report on undergraduate student housing.

In an effort to respond more fully to the complexities of long-range planning at M.I.T., a research and analysis section was recently created in this group to complement its planning and design section. The addition of new staff in this section will enable the Planning Office to accelerate the preparation of technical reports and background papers for use by the Institute community in general as well as by other Planning Office staff. The research and analysis section is also responsible for developing systematic techniques for capital programming. Work was begun late this year on developing a computer model to assist in analyzing the consequences of alternative long-range development programs. Dr. George N. Kurilko was appointed assistant planning officer for long-range planning midway through the year. In addition to assuming this responsibility in the Planning Office, he serves as liaison with both the Faculty and the Student Committees on Environment and with other members of the Institute community who wish to participate in planning its future growth and development.

#### SPACE ADMINISTRATION

Space administration includes planning, determination or evaluation of requirements, preliminary cost estimating, space change scheduling, negotiations, budget preparation, accounting, monitoring, assignments, surveys, inventory input, and studies regarding existing spaces of the Institute. It is a service to the community and, as such, it is not performed by a single office, though coordinating responsibility lies with Robert B. Cavanaugh, assistant planning officer for space administration.

Space policies are formulated by the Committee for Research and Space Planning, and decisions made by a subcommittee composed of the Provost; the Vice President, Academic Administration and Personnel; the Vice President, Organization Systems; the Comptroller; the Vice

President, Operations; and the Planning Officer. Interested parties are frequently invited to participate in the meetings and supply information or assist in decision making.

Having introduced a number of substantial procedural innovations last year, an attempt has been made during this year to conform with, reinforce, and improve existing space administration procedures. We have found that adherence to recognized procedure, in this case, provides a more nearly stable condition whereby departments and offices can effectively request satisfaction of space needs, learn the limitations of space resources, and the capacity of services available.

Increasing use is being made of student talent and ideas in design and planning for changes in existing space. Where interest is expressed and service is offered, students have been asked to participate in all phases of space change projects. In most cases the experience has been successful, with valuable training obtained by the students and assistance provided to the staff.

Eighty individual space change projects were in progress during the fiscal year. Projects ranged in size from a simple partition change in Building 20, for example, to the start of a major renovation and redesign of the third and fourth floors of Building 33. Other major projects were the conversion of the Library Lounge in Building 14 to offices and a seminar room for the Department of Humanities and a complete renovation of the south rooms, first floor of the Walker Memorial Building. In most cases, space change alterations were prompted by a change in function or occupant. An attempt is also made, however, to improve the utility of the space with each project. Aging spaces are frequently given new vitality through modernization of utilities and design improvement while undergoing space change renovations.

#### **BUILDING PROGRAM AND DESIGN REVIEW**

During this year, the building program and design review group, under the direction of Harry P. Portnoy, senior architect, has been engaged in the preparation of a wide variety of preliminary proposals, final programs, and reviews of projects under design. It has worked closely with faculty and students, seeking to provide a broad range of involvement of the M.I.T. community in the planning and development process.

The following list indicates the scope of these efforts:

#### **MAC GREGOR HOUSE**

Final design review was conducted on this project during the summer of 1968, as it moved from the planning phase into the construction phase. The first of the new houses at M.I.T., it will serve 325 residents and

should make a significant contribution to the quality of undergraduate residential life.

**ELECTRICAL ENGINEERING AND COMMUNICATIONS RESEARCH FACILITY**

Design reviews of the proposed building were conducted throughout the year with members of the client team that included Professors Louis D. Smullin, Paul L. Penfield, Henry J. Zimmermann, Samuel J. Mason, Research Associate Dean A. Powers, and other members of the Department of Electrical Engineering, the Research Laboratory of Electronics, and Institute personnel. The largest single building to be undertaken by the Institute since 1914, it will provide a more effective environment for the electrical engineering community. Located on Vassar Street, it will be physically connected to the Information Processing Center, the Compton Laboratory, and Building 24.

**MASSACHUSETTS AVENUE CROSSING**

Final designs for this project were completed during the year, and continuing reviews were conducted with Professor Alexander J. Bone and the Institute's traffic consultants, the Cambridge Traffic Department, the Cambridge Planning Board, the Cambridge Public Works Department, the Citizen's Advisory Committee, the Office of the City Manager, and the City Council. With the approval of public agencies, a number of tests were undertaken to prove out a number of the design elements in the plan. These tests revealed that the use of an integrated traffic light system, street graphics, and coordinated pedestrian crossing and traffic flow have made a significant improvement in pedestrian safety at the major crossing points along the Avenue. Late this year, the Institute received permission from the City Manager to proceed with the next phase of this project, which will include the installation of permanent traffic lights, street lighting, bus shelters, and signs.

**CLASSROOMS**

Preparing for the second year of the Classroom Renovation Program, the Planning staff reviewed with the Faculty Council and the Faculty and Student Committees on Environment the results of the first year's work. The renovated classrooms in Buildings 4, 3, and 1 have been well received and represent a striking contrast to the main body of the Institute's classrooms. New physical arrangements, materials, comfortable furnishings, better lighting, improved acoustics, and color have been employed in these new renovations. Planning for the second year's program included the preparation of a program for the lecture hall in 6-120. With the assistance of the Departments of Physics and Chemistry, the



## PLANNING OFFICE

lecture hall is being redesigned to incorporate some of the best audio-visual devices and techniques available. Classrooms and seminar rooms in Buildings 14, 33, 8, and 7 are planned for renovation in the coming year.

### HOUSING RENOVATIONS

A series of renovations to Ashdown House, East Campus, and Senior House were undertaken this year. These projects involved design and review meetings with the architect, representatives of the respective residences, faculty, and housing personnel. These renovations have given new life and spirit to some of the drabest parts of the Institute's residential environment.

### BURTON-CONNER HOUSE

Continuing review of the major renovation proposed for Burton-Conner House was conducted in a series of monthly review sessions held at Professor Herbert H. Woodson's apartment. The client team included the president of the house, John Head, Paul E. Johnston, Leonard A. Distaso, Arthur T. Hamilton, Arthur Greenberg, and Edward A. Parks, all officers or representatives of the house, the Housing Office, and Physical Plant department.

### RENOVATION TO BUILDING 33

Review of the designs for renovations to Building 33 were conducted by Professor Raymond L. Bisplinghoff, Professor Rene H. Miller, other faculty members and students of the Department of Aeronautics and Astronautics. Work on the first phase of this project began at the end of the spring term.

### CHEMICAL ENGINEERING

A preliminary report for the Department of Chemical Engineering for proposed new facilities was developed with the assistance of Professors Edwin R. Gilliland and Raymond F. Baddour. This report establishes the physical needs, planning options, and financial implications attending the Department's future growth and development. It is generally agreed that the best location for the Department is on its present site. This will require the demolition of the present Building 12 and the construction of a larger facility that will be linked physically to Building 4, the Bush Building, and the Dorrance Laboratory.

### PHYSICS-LABORATORY FOR NUCLEAR SCIENCE PROJECT

Nearing completion is the program for the proposed Physics-Laboratory for Nuclear Science (L.N.S.) facility. This program is being developed

#### VICE PRESIDENT, ORGANIZATION SYSTEMS

with the assistance of Malcolm M. Hubbard, Donald H. Gould, members of the faculty and graduate and undergraduate physics students. The programming for so large and complex a community as this is has been aided immeasurably by the Physics Council, members of the Department who are undertaking research in teaching methods in physics, students who have participated in both the teaching research and interview process, and those faculty members who have given generously of their time toward the review of techniques for utilizing new teaching methods such as closed-circuit television, and other audio-visual devices.

#### DEPARTMENT OF MATHEMATICS

A preliminary program for major renovations for the Department of Mathematics was completed this year. This program marks another step in the development of the plan for the School of Science. Professor Kenneth M. Hoffman and others in the Department of Mathematics participated in the development of this program and its presentation to the Dean of Science. It envisions a major renovation of Building 2 and parts of Building 4.

#### THE M.I.T. PRESS

With the assistance of Carroll G. Bowen, Edward W. Haas, and other members of The M.I.T. Press, a program for the renovation of Building E32, for the installation of The M.I.T. Press, was prepared and issued. This project will provide badly needed additional space for the growth of the Press. Design of this project is now under way.

#### THE BUSH BUILDING LOBBY

Several reviews of this project were conducted by the Committee on Visual Arts chaired by Professor Wayne V. Andersen. As a result of these reviews, instructions were given to the architect and new designs were under way at the close of the school year.

#### M.I.T. ENVIRONMENT STUDY

Undertaken at the beginning of the year, the M.I.T. Environment Study being prepared by the Cambridge Seven Associates, Architects, has as its client team Dean Lawrence B. Anderson and Professors Wayne Andersen, Gyorgy Kepes, and Henry A. Millon, along with Richard L. Evans, of the Student Committee on Environment, and William H. Combs of the Physical Plant. A public review of environmental problems and possibilities was conducted in December for the M.I.T. community by Paul Dietrich of the Cambridge Seven, and the client team. Later in the spring the architects assisted a group of students in developing a color

#### PLANNING OFFICE

scheme for the Building 8 corridor. This design was duly executed and has been a most useful source of comment and ideas for the larger project. At the close of the term, a special projection device in the form of a silver rhomboid was placed in the lobby of Building 7 to display the recommendations of the architects for improvements in the M.I.T. environment. The tallying of responses to these recommendations and a final report will be forthcoming shortly.

#### WALKER MEMORIAL RENOVATION

The Walker Memorial Renovation Program was reviewed by a team that included John B. L. Harkness, president of the Graduate Student Council, and other graduate students. Deans Robert J. Holden and Jay C. Hammerness, representing the office of the Dean for Student Affairs, participated as members of the team, and designs were recommended and approved for execution. The first phase of this program will see the first and second floors of the south wing of Walker Memorial repainted and a newly furnished Common Room and Graduate Student Council Office installed on the first floor.

#### LANDSCAPE PROJECT

Planning for landscape improvements this year included proposals for completing the Eastman Court as the new Camille Dreyfus Building for chemistry is finished. Studies of a major sculpture or fountain in this location have been under discussion and study, and, if funds are available, could be installed within a year or two. Temporary plantings along Vassar Street at the Space Research and Information Processing Centers will be replaced with permanent tubs and plant materials.

Because of the extensive utility lines underground in this area, no major trees can be planted. The general landscape program developed during this year envisions the improvement of areas north of the Dorrance and Whitaker Buildings, south of the Wind Tunnel at Building 17, around the new rotary between the swimming pool and Building 58, the completion of tree planting along Amherst Street, south of Kresge Auditorium, by thinning out and replanting the rapidly maturing and crowded grove of sycamores south of the Chapel, and the installation of permanent flower tubs at the Center for Advanced Engineering Study. In addition, landscape improvements were made at East Campus, Senior Court, and Baker House.

#### J. B. CARR INDOOR TENNIS FACILITY

Feasibility and design studies for the J. B. Carr Indoor Tennis Facility were developed with the assistance of Professor Ross H. Smith. The location of this highly desirable addition to our athletic plant has not yet

been resolved, which may require a delay in its execution. A number of design proposals were developed for this facility, and these were reviewed in detail with the Athletic Department.

#### GRADUATE HOUSING

With the assistance of Dean Kenneth R. Wadleigh, Laurence H. Bishoff, and a group of graduate students led by Mr. Harkness of the Graduate Student Council, a program for additional graduate housing to be located at Westgate was prepared. The proposed housing is being designed initially for single graduate students in apartment facilities. However, the program and design will provide for conversion to married student housing in part or in whole, as the need arises. Included in this program is the possibility that new means of construction, particularly those which provide for more rapid building erection, may be employed. Some of these techniques have been developed at the Institute, and we are now exploring the feasibility of using them in this project.

#### MEDICAL DEPARTMENT

A program for the renovation of the former Sancta Maria Hospital for use by the Medical Department was prepared with the assistance of Dr. Samuel D. Clark, Mrs. Dorothy B. Brooks, and Leo D. Caplice. This project will provide temporary relief for the Medical Department until permanent facilities can be developed. As a part of this effort, a study was made of the building's potential use as student housing. Such a use could follow the future evacuation of the building by the Medical Department.

#### PLANNING SYSTEMS

The planning systems group, under the direction of Kreon L. Cyros, is responsible for developing, maintaining, and improving a total information system for M.I.T. building space. The system is to provide space inventory reports, as required, for the Institute's numerous academic and administrative offices as well as space analysis capabilities for the Planning Office. Considerable effort was expended this year in expanding the inventory system not only to allow for broader reporting capacities, but to interface with a future personnel data base which can provide the data required for the study of space utilization.

Other space inventory-related efforts that took place included the creation of an automated file of M.I.T. building characteristics. Although initially conceived to provide remote-access, on-line retrieval of information in answer to specific building characteristic queries originated by the Planning Office, the immediate objectives are to publish this data on a limited basis as a working reference document. Also accomplished was

a program for providing a series of traditional building ratios, computed from the existing square-foot data.

A significant effort was also expended this year in submitting a completed inventory of physical facilities to both the Department of Health, Education, and Welfare and the Massachusetts Higher Education Facilities Inventory Project.

An equally important responsibility of the planning systems group is to provide the Planning Office with a systems consultant resource which can advise, recommend, and direct a systems approach to the planning process and to make available the technical expertise required to design and implement computer applications when needed. Specific accomplishments in the former area include the involvement of the planning systems group with the Department of Electrical Engineering's computerized experiment to provide its members with the latest architectural design status of their new building via remote consoles throughout the Department. As a result of encouraging this kind of experimentation, the planning systems group is better prepared to increase the extent of its systems approach to the architectural program currently being developed by the Planning Office for the new physics facility. Other examples of the group's involvement with a systematic approach include a program evaluation and review system to control the Planning Office's internal activities and external commitments, and a methodology for controlling, storing, and retrieving all of the documents originating from, or coming into, the office.

Specific computer applications originating from the planning systems group during these last 12 months include a program for evaluating the relative quantitative merits of providing a high-rise versus a low-rise facility of equal gross floor area on a given lot size. Another computer application just beginning involves the digitizing of a Cambridge base map, in order to provide the capability of graphically displaying topological and demographic data. This data is in the planning process by both the Institute and the Cambridge community.

The final, yet potentially most rewarding responsibility of the planning systems group is to provide yet another sounding board and workshop within the Planning Office for student participation in the planning process, in order to make the process as sensitive to community involvement as possible. The past year has found the planning systems group a focal point for several excellent student papers and term reports dealing with such subjects as "Coupling Space and Function," and "Management Information System for Building Space at M.I.T." The results of several of these papers and reports have already found their way into our system for the collection and analysis of space inventory data.

As of this writing, the former report has resulted in providing this office with an excellent framework from which we can further study and understand space utilization, while the latter report has provided the space management function of this Planning Office with a more informative means by which space change requests might be documented.

#### COMMUNITY DEVELOPMENT

At the top of most official and citizens' lists of problems was the shortage of reasonably priced housing. In 1966 municipal and university concern for this problem stimulated the establishment of the office of the Assistant City Manager for Community Development and a Community Development Program which seeks to understand and provide, among other things, for community housing needs. While these studies have been under way, the housing problem, particularly for the elderly and low-income families, has worsened. Early in the fall the Institute announced the first of a series of housing proposals for members of both Cambridge and the M.I.T. community. This first project envisions the demolition of the former Beckwith-Arden Plant on Clarendon Avenue in north Cambridge, and the construction of nonprofit rental or cooperative housing for needy members of the community. The Cambridge Corporation is providing assistance in this project through community interviews that will reveal the particular needs and desires of the neighborhood.

The problem of housing for the elderly was dramatized by the Cambridge Housing Convention that was established in late summer by the Cambridge Economic Opportunity Committee, after a sample survey of the elderly in several parts of the city indicated that there was a range of housing needs, particularly for the elderly, that the community was not meeting. Part of the Convention's focus was an expression of concern that the presence and growth of the universities in Cambridge provided an undiminishing pressure on the housing market, which in turn had dire effects on the cost of housing for low-income and elderly families. Thus, the major portion of the efforts of the community development group was focused on the housing problem, defining the scope of the problem, and outlining possible ranges of solutions and potential roles for M.I.T. in effecting the solutions.

Essential to the definition of the housing problem was an analysis of the impact of the Institute on the Cambridge housing market. Careful statistical studies were prepared and the results made available to government and citizen groups concerned with the problem. Through meetings with members of the Cambridge Housing Convention, many misconceptions of the Institute's policies and plans were eliminated. The exact nature of the problem was brought into clearer focus, and the Institute's

desire to work closely with its fellow Cantabrigians in finding ways to alleviate or eliminate this shortage was clearly established.

The Institute made its commitment clear in April, when it announced a plan to create 1,600 new dwelling units in the city. These dwelling units will be available to both Institute and Cambridge families. They will be developed so that about half of the new dwelling units will be available to Cambridge families requiring subsidy, and the other half will be available at normal nonprofit market rents. In this way the Institute has sought to begin a process which will seek to increase significantly the housing inventory of the city. In addition, our own campus housing program was accelerated in order to develop an additional 800 housing units for M.I.T. students, and in particular, single graduate students.

One important manifestation of the desire of the city's various components to work together to solve the housing crisis has been the establishment of the City Manager's Task Force on Housing. This task force provides another opportunity for the Institute to participate with the city government in solving important planning and development problems. The Planning Officer is a member of the task force.

In addition to working with citizen groups and the city government, we have been exploring with other members of the M.I.T. community the potential application of their projects or studies to Cambridge. We have begun to explore these possibilities with several members of the School of Architecture and Planning, the Department of Civil Engineering, the Urban Systems Laboratory, and the Joint Center for Urban Studies.

Coupled with this investigation of M.I.T. resources, the community development staff has been exploring in detail state and Federal housing programs that might be utilized in Cambridge. Consistent with M.I.T.'s educational and research role, we are most attracted by programs offering encouragement to experimental and innovative approaches to housing.

The Planning staff examined various housing projects now under way that have used new technology in housing development. These have included transportable housing, prefabricated parts, and other building systems. In addition, we have collected and synthesized methods of insuring maximum citizen participation in the development of housing and new combinations of several subsidy housing programs.

Community housing programs promise to command an increasing portion of the attention of the community development staff in the next few years. Participation in the planning and implementation of the low- and moderate-income housing program, part of a larger comprehensive housing program announced by M.I.T. this spring, will require careful development and extension of relationships and associations built up over

the years between M.I.T. and the community. New relationships will be established through work on the housing program, and our efforts will be focused on insuring that the program meets the needs of those for whom it was intended. In this connection, a series of meetings with various planning teams and neighborhood groups has been initiated. Through these meetings, specific neighborhood needs and priorities will be established. The community development staff, working with the Institute Real Estate Office, hopes to be able to make useful contributions to this overall program.

Gordon Brigham, the assistant planning officer for community development, on leave last year to initiate Cambridge's Community Development Program, was asked at the beginning of the year to undertake the leadership of the Cambridge Model Cities Program. In that capacity he has been director of the Model Cities Program and has been fully engaged in preparing, during this year, final program applications for funding of the Model Cities Program. It is expected that this program will be funded, and that Cambridge will have an opportunity to demonstrate the efficacy of a truly citizen-planned and managed Model Cities Program.

O. ROBERT SIMHA



## **OTHER OFFICES**

### **DEPARTMENT OF AEROSPACE STUDIES**

At the beginning of the academic year there were 57 cadets enrolled in the Air Force R.O.T.C. program. Of these, 29 were in the General Military Course (Basic Course), and 28 in the Professional Officer Course (Advanced Course).

The annual gaming exercise, POLMILEX VI, was held on May 3, 1969, for members of the General Military Course. The game was built around a situation in South America.

During the academic year, nine seniors, seven juniors, seven sophomores, and two freshmen were on Financial Assistance Grants, authorized by the R.O.T.C. Vitalization Act of 1964.

### **CADET ACTIVITIES**

The Department sponsored three base familiarization visits during the year. On November 28, 1968, ten cadets visited Andrews Air Force Base for a briefing on the mission and organization of the Air Force Systems Command. Between March 30 and April 4, five cadets received orientation briefings and visited the facilities at Holloman Air Force Base, New Mexico; Kirtland Air Force Base, New Mexico; and the United States Air Force Academy, Colorado Springs, Colorado. The trip was sponsored by Dr. Ernst A. Steinhoff, Chief Scientist at the Missile Development Center, and Visiting Professor in the Department of Aeronautics and Astronautics for the year. In April, 1969, four senior cadets visited L. G. Hanscom Field, as guests of the Junior Officers' Council. They learned about life as a young lieutenant in Air Force research and development.

#### OTHER OFFICES

The cadets directed the annual Dining-In held on October 8, 1968. The guest speaker for the occasion was Lt. Colonel Cornelius J. Gearin Jr., U.S.A. He is a research associate at the Center for International Studies and spoke on some of the myths and misconceptions concerning Vietnam.

#### M.I.T. A.F.R.O.T.C. GRADUATES

During the academic year, nine cadets received commissions in the Air Force. Four were named as Distinguished Military Graduates and three were selected for appointment as Regular Air Force Officers. One commissionee received a graduate degree and has been assigned to Wright-Patterson Air Force Base, Ohio. The eight others were granted educational delays to complete studies for advanced degrees. The Air Force continues as a policy to grant educational delays to those individuals desiring to go immediately to graduate school and to assign graduates to fields requiring the specialties developed in their academic training.

GEORGE P. GAMACHE

#### DEPARTMENT OF MILITARY SCIENCE

Army R.O.T.C. continued its upward swing in enrollment with an end-of-the-year total of 88. This year also saw the inception of a new developmental curriculum as part of the Army's continued effort to revitalize the program and make it more attractive and compatible with the academic atmosphere of the college student.

The Army R.O.T.C. innovated a new tri-service Military Day activity on May 20th of this year. Awards and decorations were presented at a banquet held at the Faculty Club. Sponsorship of this activity was funded by the Institute and attended by more than 215 people including cadets.

Thirteen seniors were commissioned during the year. One received a Regular Army commission in September, three received Regular Army commissions, and nine were recipients of Reserve commissions in June. The three students receiving Regular Army commissions in June were also awarded graduate school scholarships of two years by attaining standing among the top 5 per cent in nationwide competition. Two additional students will be commissioned upon completion of summer camp; one Regular Army and one Reserve. The Regular Army commissionee is an additional winner of the graduate two-year scholarship award. The total of five Regular Army commissions is the highest for the Army R.O.T.C. Program since the end of World War II. The fact that four of these placed among the top 5 per cent of graduates nationwide attests to the quality of M.I.T. cadets.

## DEPARTMENT OF NAVAL SCIENCE

### SCHOLARSHIPS

Seven new freshmen were awarded four-year Army R.O.T.C. Scholarships, and two sophomores were awarded the two-year Army R.O.T.C. Scholarships. This brings the total of Army R.O.T.C. Scholarships at M.I.T. to 32.

### PERSONNEL

The appointment of Major David B. Smith was terminated in April. He was reassigned to Vietnam with temporary duty enroute for additional schooling at Fort Sill, Oklahoma. His replacement, Major Stanley H. Hyman, has been nominated and approved by the Institute and will assume his new duties in September. Master Sergeant Henry L. Whalen's appointment was terminated in June and he was reassigned to Vietnam. Staff Sergeant Louis Williams Jr.'s appointment was terminated in June and he was reassigned to Thailand. SP5 Peter Rose's appointment was terminated in April. Nominations to replace these terminated personnel are expected sometime during the summer.

MARSHALL O. BECKER

## DEPARTMENT OF NAVAL SCIENCE

There were three seniors in the graduating class this year who received commissions in the United States Naval Reserve in commissioning exercises on June 12, 1969. One senior will receive his commission upon completion of his academic program in January, 1970, and will enter active duty at that time.

A total of 33 midshipmen remained in the Naval R.O.T.C. after graduation: 12 seniors, 11 juniors, and 10 sophomores. The freshman enrollment will be accomplished in September. This unit also administered to 100 postgraduate officers of the United States Navy, United States Coast Guard and the navies of foreign countries, plus nine Naval Enlisted Scientific Education Program Students.

### PERSONNEL

Captain Dean A. Horn assumed command in August, 1968, and was joined by Commander Harold O. McEachern as Executive Officer in September. Lieutenant Orval F. Thorson, who will be released from active duty in the Navy in August, has been relieved by Lieutenant John H. Beaton. Chief Storekeeper Charles V. Weaver was relieved by Chief Storekeeper Mike D. Monk in May, 1969, while Chief Yeoman Robert A. Erickson will be relieved by Chief Yeoman William F. Welch in August.

These replacements will maintain the present staff level of eight for the coming academic year.

DEAN A. HORN

### ALUMNI ASSOCIATION

Since its founding in 1875, the purpose of the Alumni Association has been "to further the well-being of the Institute by fostering the interest of the alumni in the Institute and in each other." To that end the principal current activities of the Association are:

1. The dissemination of information relevant to M.I.T. through the *Technology Review*, newsletters, and reports
2. The encouragement and solicitation of financial support to M.I.T. by alumni
3. The promotion of campus meetings
4. The improvement and strengthening of the relations of M.I.T. with its alumni through class and course organizations and the 98 organized M.I.T. clubs.

On April 1, the membership rolls of the Association included 57,981 names, a net gain of 871 over the preceding 12 months by reason of adding 1,353 new alumni of the Class of 1968 and the subtraction of the names of 482 alumni reported deceased. During the previous 12 months, 10,519 address changes were recorded. The number of alumni in the "Address Missing" category totaled 3,129 or 5 per cent of our roster.

In 1969, for the sixth consecutive year, the Alumni Fund set new records: \$2,680,077 from 19,829 donors. In a year when major alumni funds generally reported losses, or at best, minor increases in numbers of donors, the M.I.T. Alumni Fund has the good fortune to report an increase of 1,058 contributors. The average increase for the last five years has been 972. Special mention should be made of the two-year term of Howard L. Richardson '31 as Chairman of the Alumni Fund Board, under whose leadership the Fund was recognized by a first prize from the American Alumni Council for sustained performance, in competition with other major private universities, and third prize among all competing institutions.

Because of the increase in graduating registration, starting especially after World War II, we are approaching the time when 40 per cent of our alumni body will have an advanced degree with no Bachelor's degree from M.I.T. The Alumni Fund participation by M.I.T. graduate alumni far surpasses all but a few special graduate schools. The following table is both encouraging and indicative of where additional efforts towards participation are due.

## ALUMNI ASSOCIATION

	Number of alumni	Per Cent Who Have Contributed
Undergraduate alumni with:		
M.I.T. Bachelor's degree	29,784	74%
No M.I.T. degree	8,540	35%
Graduate alumni:		
M.I.T. advanced degree only	13,535	49%
No M.I.T. degree	2,993	21%
Total	54,852	59%

During the year, the Fund's class reunion and geographic programs were strengthened and two new programs were introduced: organization of graduate students on a departmental basis and formation of a committee to conduct a parents' solicitation. These have much future promise as they evolve from their present formative stages. The year also witnessed recognition of the Fund as a major vehicle for communicating concerns between the staff and small groups of alumni throughout the country. Details on reunion gifts and other aspects of the Fund are included in the Fund's annual report to all alumni.

The program to enhance the content and circulation of *Technology Review*, conceived by the Association's Long-Range Planning Committee, encouraged and aided by the Editorial Advisory Board for the second year under Gregory Smith's chairmanship, has been further fulfilled during 1968-69. The editorial content of volume 71, expanded in keeping with the readership survey initiated a year ago, has remained distinguished. The volume included three special issues, "Natural Sciences in the Year 2000," "Computers in the Service of Society," which was developed from the 1968 Alumni Seminar, and "The Sakharov Paper," as well as a large number of first-quality original papers. Increasingly, the *Review* is being quoted by the press and other magazines, including abstracting journals. There is also a growing demand for complete reprints and for permission to reprint for purposes ranging from teaching to book publication.

At the annual conference of the American Alumni Council in July, *Technology Review* was, for the third consecutive year, named among the ten best alumni magazines in the United States. During the previous spring, the *Review* had received three awards for its design in a professional competition conducted by the Society of Publication Designers. In a year when most professional journals have experienced modest declines in advertising income, *Technology Review* has achieved a modest increase.

A notable accomplishment of the year has been to broaden the *Review's* paid, nonalumni circulation through direct mail promotion. In one year the number of nonalumni subscribers has grown from 1,250 to nearly 5,000. This year's experience has given us confidence to intensify these efforts for increased nonalumni circulation — thereby extending M.I.T.'s influence, yielding substantial circulation income, permitting higher advertising rates, and attracting thoughtful faculty authors through the larger and broader base of readership.

The Ninth National Alumni Officers Conference was held at M.I.T. in September with a record of 684 alumni officers and wives taking part. At the Alumni Seminar, 250 alumni and wives heard lectures and discussions, led by distinguished faculty and outside speakers, on the development and impact of the computer sciences. In June, 1,340 returning alumni and guests enjoyed 13 campus reunions and 1,255 attended Homecoming Day activities, including 700 who attended both. Student-Alumni Weekend was again conducted by undergraduates.

Of the 98 M.I.T. Clubs around the world, the 74 in North America reported 156 meetings with attendance totaling more than 12,000 alumni and guests. This year the Director for Clubs concentrated his efforts on the larger clubs, emphasizing the qualifications and techniques of leadership for voluntary organizations. There were 75 visits by Association staff specifically for club purposes. More important, there were 80 club visits by faculty and 9 by undergraduates. We are mindful that many who have participated in this program have often done so at considerable inconvenience to themselves. Outstanding programs were the Regional Conferences in St. Louis and Long Island, the Twenty-First Annual Fiesta in Mexico City, Boston's uniformly well-attended monthly luncheons, and New York's remarkable set of programs including a tour of the Whitney Museum of American Art, a full house at Carnegie Hall for the M.I.T. Symphony Orchestra, and the seminar at Arden House, "Strengthening Management for the Seventies."

We are especially indebted to William S. Edgerly '49 who, as chairman for two years, has ably guided the Alumni Club Advisory Board as it has assumed the responsibility for guiding, motivating, and evaluating regional leadership.

This year we were fortunate to add to our staff Panos D. Spiliakos '66, as Assistant Secretary of the Alumni Association; Clyde C. Hall as Acting Managing Editor of *Technology Review* until the arrival in January of Fred Wheeler, formerly Technology Editor of the London *New Scientist*; and Deborah Shapley and Lynn Thomas as Associate Editors.

Resignations included T. Guy Spencer '56 from his position as Associate Director of the Alumni Fund, Roy A. Johnson '50, Associate Direc-

ALUMNI ASSOCIATION

tor of the Alumni Fund, Ann Peterson, Administrative Assistant, and Russell B. Higley, who had joined the Alumni Fund staff earlier this year. Ruth King's retirement from the position of Associate Editor after 40 years' devoted service to *Technology Review* leaves a void which will not easily be filled.

The Alumni Association has experienced a very successful year. Since the completion of the Long-Range Planning Committee Report, one-third of its 140 recommendations have been completed, and another 57 are in process. The Association's accomplishments depend directly on the thousands of alumni volunteers and their leadership: members of the Corporation and its departmental visiting committees; club and class officers; members of the Educational Council; and those working on behalf of the Alumni Fund. Special tribute should be paid Cecil H. Green '23, 75th President of the Alumni Association, whose dedicated service to the Institute has been an inspiration to his associates and a credit to the Institute.

DONALD P. SEVERANCE





## **PRINCIPAL PROFESSIONAL HONORS AND ACTIVITIES OF THE STAFF**

### **INSTITUTE PROFESSORS**

#### **MANSON BENEDICT**

Robert E. Wilson Award in Nuclear Chemical Engineering, American Institute of Chemical Engineering.

Citation for Contributions to U.S. Atomic Energy Programs, U.S. Atomic Energy Commission.

Arthur Holly Compton Award, American Nuclear Society.

#### **HAROLD E. EDGERTON**

Honorary degree of Doctor of Laws, University of South Carolina.

Honorary degree of Doctor of Laws, Doane College.

John Oliver Lagorce Gold Medal, National Geographic Society.

Honorary Membership, Society of Motion Picture and Television Engineers.

Eminent Member Award, Eta Kappa Nu.

#### **ROMAN JOKOBSON**

Honorary degree of Doctor of Theological Science, Charles University, Prague, Czechoslovakia.

Honorary degree of Doctor of Theological Science, Purkyně University, Brno, Czechoslovakia.

Honorary degree of Doctor of Science, Clark University.

Golden Medal, Slovak Academy of Sciences.

Honorary Member, Academy of Aphasia.

#### **PAUL A. SAMUELSON**

President, International Economic Association.

Member, Commission on the Social Sciences, National Science Foundation.

#### **FRANCIS O. SCHMITT**

Foreign Member, Royal Swedish Academy of Sciences.

#### **JERROLD R. ZACHARIAS**

Honorary degree of Doctor of Laws, Jacksonville University.

Citation for Distinguished Service to Science Education, National Science Teachers Association.

### **SCHOOL OF ARCHITECTURE AND PLANNING**

#### **DEPARTMENT OF ARCHITECTURE**

#### **STANFORD ANDERSON**

Member, Board of Directors, Society of Architectural Historians.

John Simon Guggenheim Memorial Foundation Fellowship.

PROFESSIONAL HONORS AND ACTIVITIES

DEPARTMENT OF URBAN STUDIES AND PLANNING

**BERNARD J. FRIEDEN**

Member, Editorial Advisory Panel, *Journal of the American Institute of Planners*.  
Member, Policy Committee, Planners for Equal Opportunity.  
Trustee, National Assembly for Social Policy and Development.

SCHOOL OF ENGINEERING

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

**NORMAN D. HAM**

Chairman, Dynamic Session, Annual National Forum of the American Helicopter Society.

Member, Dynamics Committee, American Helicopter Society.

**WALTER M. HOLLISTER**

Member, Technical Committee for Astrodynamics, American Institute of Aeronautics and Astronautics.

**JEROME C. HUNSAKER**

Julius Adams Stratton Prize for Cultural Achievement, Friends of Switzerland.

**W. STEPHEN LEWELLEN**

Member, Fluid Dynamics Technical Committee, American Institute of Aeronautics and Astronautics.

**RENE H. MILLER**

The Klemin Award, American Helicopter Society.

Decoration for Meritorious Civilian Service, U.S. Army.

Sylvanus Albert Reed Award, American Institute of Aeronautics and Astronautics.

**DAVID A. OLIVER**

Member, Steering Committee, Symposium on Engineering Aspects of Magneto-hydrodynamics.

**LEON TRILLING**

Chairman, Sixth International Symposium on Rarefied Gas Dynamics.

**WALLACE E. VANDER VELDE**

Member, Technical Committee on Guidance and Control, American Institute of Aeronautics and Astronautics.

**HAROLD Y. WACHMAN**

Co-chairman, Sixth International Symposium on Rarefied Gas Dynamics.

**WALTER WRIGLEY**

Fellow, American Institute of Aeronautics and Astronautics.

**LAURENCE R. YOUNG**

Member, Cardiovascular Panel, National Academy of Sciences.

Member, Technical Specialty Group on Vehicle Systems for Launch Space Entry and Missiles, American Institute of Aeronautics and Astronautics.

Member, Man-Machine Systems Advisory Committee, Institute of Electrical and Electronics Engineers.

DEPARTMENT OF CHEMICAL ENGINEERING

**PIERRE L. THIBAUT BRIAN**

Overseas Fellow, Churchill College, University of Cambridge, Cambridge, England.

**THOMAS B. DREW**

Max Jakob Memorial Award, American Society of Mechanical Engineers and American Institute of Chemical Engineers.

**EDWIN R. GILLILAND**

Warren K. Lewis Professor of Chemical Engineering.

## HONORS AND AWARDS

**MICHAEL MODELL**

Chairman, Catalysis Club of New England.

**ROBERT C. REID**

Council Member, American Institute of Chemical Engineering.

**ADEL F. SAROFIM**

Member, Editorial Board, *Solar Energy Society Journal*.

**CHARLES N. SATTERFIELD**

Member, Editorial Advisory Board, *Industrial and Engineering Chemistry*.

## DEPARTMENT OF CIVIL ENGINEERING

**JOHN B. BABCOCK III**

Honorary Member, Boston Society of Civil Engineers.

**JOHN M. BIGGS**

Member, Executive Committee, Structural Division, American Society of Civil Engineers.

**JOHN T. CHRISTIAN**

Member, Committee on Computer Applications of Soil Mechanics and Foundations Division, American Society of Civil Engineers.

Member, Highway Research Board.

**ROBERT J. HANSEN**

Distinguished Service Citation, Department of Defense.

**DONALD R. F. HARLEMAN**

John Simon Guggenheim Memorial Foundation Fellowship.

**ALAN M. HERSHDORFER**

Chairman, Special Interest Group on Planning, Architecture, Civil Engineering, and Urban Data Systems, Association for Computing Machinery.

**ARTHUR T. IPPEN**

Honorary degree of Doctor of Science, University of Manchester, Manchester, England.

**RUSSEL C. JONES**

Vice President, Massachusetts Section, American Society of Civil Engineers.

Chairman, National Subcommittee on Guidance, American Society of Civil Engineers.

Vice Chairman, Committee on Mechanical Properties of Materials, Engineering Mechanics Division, American Society of Civil Engineers.

**MARVIN L. MANHEIM**

Regional Editor, *Transportation Research*.

Academic Vice President, Transportation Research Forum.

Member, Long Range Planning Committee, Highway Research Board, National Academy of Sciences-National Research Council.

Participant, Exploratory Meeting on Transportation Analysis and Planning, Organization for Economic Cooperation and Development.

Chairman, Editorial Advisory Board, Design Methods Group.

**ANWAR E. Z. WISSA**

Chairman, Committee on Soil Bituminous Stabilization and Member, Committee on Soil Cement Stabilization, Highway Research Board.

Member, Committee on Placement and Improvement of Soils, American Society of Civil Engineers.

## DEPARTMENT OF ELECTRICAL ENGINEERING

**FLOYD O. ARNTZ**

Chairman, New England Chapter, Thin Film Division, American Vacuum Society.

PROFESSIONAL HONORS AND ACTIVITIES

**MICHAEL ATHANS**

Vice Chairman, Information Dissemination Committee and Member, Administrative Committee, Group on Automatic Control, Institute of Electrical and Electronics Engineers.

Senior Member, Institute of Electrical and Electronics Engineers.

F. E. Terman Award, Electrical Engineering Division, American Society for Engineering Education.

**GORDON S. BROWN**

Chairman, Commission on Education and Member, Council, National Academy of Engineering.

**JACK CAPON**

Chairman, Group on Information Theory, Boston Chapter, Institute of Electrical and Electronics Engineers.

**MICHAEL L. DERTOUZOS**

U.S. Delegate of the Institute of Electrical and Electronics Engineers to Annual Meeting of U.S.S.R. Popov Society.

**JOHN J. DONOVAN**

David Schultz Award, Department of Electrical Engineering, Massachusetts Institute of Technology.

**ROBERT M. FANO**

Chairman, Panel on Computers and Society, Committee on the Year 2000, American Academy of Arts and Sciences.

**ROBERT R. FENICHEL**

Visiting Senior Fellow, University Mathematical Lab, Cambridge, England.

**LEONARD A. GOULD**

Visiting Professor, Department of Applied Physics, Chr. Michelsen Institute, Bergen, Norway.

**JOSEPH C. R. LICKLIDER**

Member, National Academy of Sciences.

**FREDERIC R. MORGENTHAUER**

Vice Chairman, Group on Microwave Theory and Techniques, Boston Chapter, Institute of Electrical and Electronic Engineers.

**ROBERT H. REDIKER**

David Sarnoff Award, Institute of Electrical and Electronics Engineers.

Fellow, American Physical Society.

**FRED C. SCHWEPPE**

Chairman, Stochastic Systems Committee, Group on Automatic Control, Institute of Electrical and Electronics Engineers.

**CAMPBELL L. SEARLE**

Counselor, Massachusetts Institute of Technology Branch  
Institute of Electronics and Electrical Engineers.

**RICHARD N. SPANN**

Member, Review Committee of Computer Science in South and Central America, Organization of American States.

**HERBERT H. WOODSON**

Member, Executive Committee, Professional Technical Group on Power, Boston Chapter, Institute of Electrical and Electronics Engineers.

Chairman, Generalized Theory Subcommittee, Rotating Machinery Committee and Member, Energy Development Subcommittee, Power Generation Committee, Institute of Electrical and Electronics Engineers.

**HENRY J. ZIMMERMANN**

Fellow, Institute of Electrical and Electronics Engineers.

## HONORS AND AWARDS

### DEPARTMENT OF MECHANICAL ENGINEERING

#### SAMUEL C. COLLINS

Member, National Academy of Sciences.  
Gold Medal, American Society of Mechanical Engineers.  
Honorary degree of Doctor of Laws, St. Andrews University.

#### STEPHEN H. CRANDALL

Chairman, Applied Mechanics Division, American Society of Mechanical Engineers.

#### C. FORBES DEWEY JR.

Member, Plasma Dynamics Technical Committee, American Institute of Aeronautics and Astronautics.

#### JAMES A. FAY

Chairman, Air Pollution Control Commission, City of Boston.

#### LEON R. GLICKSMAN

Robert T. Knapp Award, Division of Fluids Engineering, American Society of Mechanical Engineers.

Melville Medal, American Society of Mechanical Engineers.

Member, Fluid Mechanics Committee, American Society of Mechanical Engineers.

#### AUGUST L. HESSELSCHWERDT JR.

Distinguished Service Award, American Society of Heating, Refrigerating and Air Conditioning Engineers.

#### ROBERT W. MANN

Member, Committee on the Interaction of Engineering with Biology and Medicine, National Academy of Engineering.

Chairman, Subcommittee on Sensory Aids, National Academy of Engineering.

Associate Editor, Institute of Electrical and Electronics Engineers *Transactions of Biomedical Engineering*.

Consultant, Department of Orthopedic Surgery, Massachusetts General Hospital.

Member, Committee on Skeletal Systems, National Research Council.

President, Board of Directors, Catholic Guild for All the Blind.

Member, Advisory Council, National Joint Braille Authority.

Chairman, Technical Committee on Standards for the Production of Reading Materials for the Blind and Visually Handicapped, American Accreditation Council.

Advisor, Commissioner for the Blind in Massachusetts.

#### RICHARD A. MOSS

Du Pont Young Faculty Grant, Massachusetts Institute of Technology.

#### EGON OROWAN

Member, National Academy of Sciences.

#### FRIEDRICH STEINMANN

Alfred Williard French Memorial Fund Stipend.

#### TAU-YI TOONG

President, East American Chapter, Phi Tau Phi Scholastic Honor Society.

Member, Editorial Advisory Board, *Combustion Science and Technology*.

#### DAVID G. WILSON

Chairman, Process-Industries Division and Chairman, Urban-Technology Subcommittee, American Society of Mechanical Engineers.

M.I.T. Urban Fellowship, Massachusetts Institute of Technology.

### DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

#### MERTON C. FLEMINGS

Mathewson Gold Medal, Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers.

#### SIMON C. MOSS

John Simon Guggenheim Memorial Foundation Fellowship.

#### PROFESSIONAL HONORS AND ACTIVITIES

**ROBERT E. OGILVIE**  
President-elect, Electron Microprobe Society.

**REGIS M. N. PELLOUX**  
Grand Prize, Metallographic Competition, American Society for Metals.

#### DEPARTMENT OF NAVAL ARCHITECTURE

**ALFRED A. H. KEIL**  
Member, Laboratory Advisory Board for Naval Ships, Naval Research Advisory Committee.

**PHILIP MANDEL**  
Member, Laboratory Advisory Board for Naval Ships, Naval Research Advisory Committee.

**ALAA E. MANSOUR**  
Ford Foundation Fellowship.  
Technical and Research Representative, New England Section, Society of Naval Architects and Marine Engineers.

**KOICHI MASUBUCHI**  
Secretary, Commission X, International Institute of Welding.

**SHERMAN C. REED**  
Secretary-Treasurer, New England Section, Society of Naval Architects and Marine Engineers.

#### DEPARTMENT OF NUCLEAR ENGINEERING

**KENT F. HANSEN**  
Chairman, Mathematics and Computation Division, American Nuclear Society.

**ALLAN F. HENRY**  
Chairman, Honors and Awards Committee, American Nuclear Society.

**EDWARD A. MASON**  
Member, National Program Committee, American Nuclear Society.  
Fellow, American Institute of Chemists.

**THOMAS O. ZIEBOLD**  
National Secretary, Electron Probe Analysis Society of America.  
Member, Committee for Nuclear Pumps and Valves, American Society of Mechanical Engineers.  
Member, Committee for Reactor Plant Construction, United States of America Standards Institute.  
Member, Executive Committee, Northeastern Section, American Nuclear Society.

#### SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

##### DEPARTMENT OF ECONOMICS

**EVSEY D. DOMAR**  
Fellow, Econometric Society.

**FRANKLIN M. FISHER**  
Irving Fisher Lecturer, Econometric Society Meeting, Amsterdam, Netherlands.  
Prize, Military Applications Section, Operations Research Society of America.  
Fellow, American Academy of Arts and Sciences.  
Editor, *Econometrica*.

**ROBERT M. SOLOW**  
George Eastman Visiting Professor and Fellow, Balliol College, University of Oxford, England.

## HONORS AND AWARDS

### DEPARTMENT OF FOREIGN LITERATURES AND LINGUISTICS

**WILLIAM F. BOTTIGLIA**

Member, Council of the Dante Society of America.

**ROBERT E. JONES**

Secretary, Institute for Thematic and Structural Studies.

### DEPARTMENT OF HUMANITIES

**JOHN E. BURCHARD**

Thomas Jefferson Memorial Medal in Architecture, University of Virginia and Thomas Jefferson Memorial Foundation.

**DAVID M. EPSTEIN**

Member, Rockefeller Foundation Commission for String Quartet.

Member, Advisory Council on Music, European Language Institute.

**ROBERT S. FREEMAN**

Fellow, National Foundation for the Humanities.

Member, Governing Board, Association of Princeton Graduate Alumni.

**THOMAS H. D. MAHONEY**

Fellow, Royal Historical Society, England.

Trustee, Newton College.

Chairman, Massachusetts State Fulbright Committee.

**HUSTON C. SMITH**

Bronze Medal, International Film and Television Festival of New York.

Birks Lecturer, McGill University, Canada.

Alumnus of the Year Citation, Divinity School, University of Chicago.

### DEPARTMENT OF POLITICAL SCIENCE

**HAYWARD R. ALKER JR.**

Member, Executive Committee, Mathematical Social Science Board.

Member, Executive Committee, International Studies Association.

**NORMAN J. PADEFORD**

Member, Founding Board of Editors *Journal of Maritime Law and Commerce*.

Chairman, Political Science Selection Committee, Woodrow Wilson National

Fellowship Foundation.

**ROSEMARIE S. ROGERS**

Ford Foundation Faculty Research Fellowship.

**EUGENE B. SKOLNIKOFF**

Carnegie Endowment Visiting Research Scholar, Geneva, Switzerland.

### DEPARTMENT OF PSYCHOLOGY

**STEPHAN L. CHOROVER**

Chairman, Division 6 Program Committee, American Psychological Association.

**RICHARD M. HELD**

Consulting Editor, *Journal of Experimental Psychology*.

Member, Editorial Board, *Perspectives in Biology and Medicine*.

Fellow, American Academy of Optometry.

Director-at-large, Eastern Psychological Association.

**WHITMAN A. RICHARDS**

Member, Committee on Vision, Armed Forces, National Research Council.

### SLOAN SCHOOL OF MANAGEMENT

**DOUGLASS V. BROWN**

President-elect, Industrial Relations Research Association.

PROFESSIONAL HONORS AND ACTIVITIES

WALLACE B. CROWSTON

Secretary-Treasurer, Boston Chapter, Institute of Management Sciences.

JAY W. FORRESTER

Inventor of the Year Award, Patent, Trademark, and Copyright Research Institute, George Washington University.

PETER G. GERSTBERGER

Member, Society of Sigma Xi.

BILLY E. GOETZ

Life Member, Society for the Advancement of Management.

DANIEL M. HOLLAND

Elizur Wright Award, American Risk and Insurance Association.

ERICH JANTSCH

Co-editor, *Technological Forecasting*.

JOHN D. C. LITTLE

Media Award, *Mediascope Magazine*.

DONALD G. MARQUIS

President, New England Psychological Association.

DAVID B. MONTGOMERY

Departmental Editor, *Management Science*.

CHARLES A. MYERS

Achievement Award, College of Business Administration Alumni Association, Pennsylvania State University.

Chairman, National Manpower Policy Task Force.

EDWARD B. ROBERTS

Visiting Forrester Chair of Military Management, Naval War College.

RICHARD D. ROBINSON

Member, Executive Committee, Institute of Current World Affairs.

President, Association for Education in International Business.

Member, Board of Directors, American Research Institute in Turkey.

IRWIN M. RUBIN

Everett Moore Baker Award, Massachusetts Institute of Technology.

ZENON S. ZANNETOS

Vice President, College on Measurements in Management, Institute of Management Sciences.

Member, Manuscript Contest Committee, American Accounting Association.

Member, Editorial Board, *Decision Sciences*.

SCHOOL OF SCIENCE

DEPARTMENT OF BIOLOGY

BORIS MAGASANIK

Member, National Academy of Sciences.

DAVID P. RICHEY

Member, Society of the Sigma Xi.

Fellow, National Institutes of Health.

PHILLIPS W. ROBBINS

Eleanor Roosevelt International Cancer Fellowship.

DEPARTMENT OF CHEMISTRY

FREDERICK D. GREENE II

Honorary degree of Doctor of Science, Amherst College.



#### HONORS AND AWARDS

LEICESTER F. HAMILTON

50 Year Award and Member, American Chemical Society.

LAWRENCE J. HEIDT

Chairman, Board of Publications and Councilor, Northeastern Section, American Chemical Society.

HERBERT O. HOUSE

Member, Editorial Boards, *Organic Reactions, Inc.* and *Organic Syntheses, Inc.*

JAMES L. KINSEY

John Simon Guggenheim Foundation Fellowship.

AHTI O. PAKKANEN

Fulbright-Hays Travel Grant.

JOHN C. SHEEHAN

Director-at-large, American Chemical Society.

Camille Dreyfus Professor of Chemistry.

DAVID P. SHOEMAKER

Chairman, U.S.A. National Committee for Crystallography.

Vice President, American Crystallographic Association.

JEFFREY I. STEINFELD

Alfred P. Sloan Research Fellowship.

Co-chairman, Gordon Research Conference on Molecular Energy Transfer.

WILLIAM H. ZOLLER

Eastman Award.

#### DEPARTMENT OF EARTH AND PLANETARY SCIENCES

MEHMET N. TOKSOZ

Vice President, Eastern Section, Seismological Society of America.

WILLIAM S. VON ARX

Fellow, American Meteorological Society.

DAVID R. WONES

Councilor, Geochemical Society.

#### DEPARTMENT OF MATHEMATICS

DONALD W. ANDERSON

Alfred P. Sloan Foundation Research Fellowship.

RICHARD M. DUDLEY

Invited Lecturer, Consortium of Universities, Washington, D.C.

ROE W. GOODMAN

Visiting Member, Institute for Advanced Study, Princeton University.

TAKESHI KOTAKE

John Simon Guggenheim Memorial Foundation Fellowship.

DANIEL G. QUILLEN

Alfred P. Sloan Foundation Research Fellowship.

ISADORE M. SINGER

Bocher Memorial Prize, American Mathematical Society.

John Simon Guggenheim Memorial Foundation Fellowship.

DIRK J. STRUIK

Member, International Academy of the History of Sciences.

#### DEPARTMENT OF METEOROLOGY

JULE G. CHARNEY

Hodgkins Gold Medal, Smithsonian Institution.

Vice President, Meteorology Section, American Geophysical Union.

PROFESSIONAL HONORS AND ACTIVITIES

**EDWARD N. LORENZ**

Carl-Gustaf Rossby Research Medal, American Meteorological Society.

**MICHAEL E. MCINTYRE**

Research Fellowship, St. John's College, Cambridge, England.

**NORMAN A. PHILLIPS**

Editors Award, American Meteorological Society.

**HENRY M. STOMMEL**

James Simon Guggenheim Award.

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

**EDWIN D. BRANSOME JR.**

Faculty Research Award, American Cancer Society.

**SAMUEL A. GOLDBLITH**

Distinguished Food Scientist Award, New York Institute of Food Technologists.

Babcock-Hart Award, Institute of Food Technologists.

**PAUL M. NEWBERNE**

Vice President, American College of Veterinary Pathologists.

President, New England Branch, American Association of Laboratory Animal Science.

Nutrition Council, American Feed Manufacturers' Association.

**LARISSA A. POHORECKY**

Member, Society of Sigma Xi.

**JOHN B. STANBURY, M.D.**

President, American Thyroid Association.

**RICHARD J. WURTMAN**

Member, American Institute of Biological Sciences Advisory Panel, Bioscience Program, National Aeronautics and Space Administration.

Member, Editorial Board, *Journal of Pharmacology and Experimental Therapeutics*.

DEPARTMENT OF PHYSICS

**ROBLEY D. EVANS**

Honorary member, Society of Nuclear Medicine.

**HERMAN FESHBACH**

Member, National Academy of Sciences.

Vice Chairman, Division of Nuclear Physics, American Physical Society.

Member, National Research Council.

**NATHANIEL H. FRANK**

Chairman, Section B, (Physics) and Vice President, American Association for Advancement of Science.

**BENJAMIN LAX**

Member, National Academy of Sciences.

Gano Dunn Medal, Cooper Union Alumni Association.

**MARGARET L. A. MACVICAR**

Marie Curie Post-doctoral Award in Physics, American Association of University Women.

**PHILIP MORRISON**

Christmas Lecturer, Royal Institution of London and BBC-TV.

Carlson Memorial Lecturer, Iowa State University.

Kennedy Memorial Lecturer, Washington University.

Failla Memorial Lecturer, Radiation Research Society.

**HARRY M. SCHEY**

Everett Moore Baker Award, Massachusetts Institute of Technology.

## HONORS AND AWARDS

### ADMINISTRATION

**RICHARD F. BENWAY**

President, Boston Guild for Hard of Hearing.

Chairman, Editorial Committee, Boston Patent Law Association.

**CARROLL G. BOWEN**

Member of the Board, Association of American University Presses.

Member of the Board, American University Press Services.

**SIEGFRIED M. BREUNING**

Member, Group Council on Transportation Systems, Planning, and Administration,  
Highway Research Board.

**EUGENE R. CHAMBERLAIN**

President, National Association for Foreign Student Affairs.

**HAROLD E. DREYER**

Member, Insurance Division Planning Council, American Management Association.

**F. LEROY FOSTER**

Chairman, Engineering College Research Council.

Vice President, American Society for Engineering Education.

**VINCENT A. FULMER**

Member, Financial Development Advisory Council, The Urban Coalition.

**WOLCOTT A. HOKANSON**

Treasurer, School District, Deerfield, New Hampshire.

Auditor, Town of Deerfield, New Hampshire.

**HOWARD W. JOHNSON**

Honorary degree of Doctor of Laws, University of Massachusetts.

Honorary degree of Doctor of Humanities, Roosevelt University.

**G. EDWARD NEALAND**

Treasurer and Member, Executive Committee, National Association of Educational  
Buyers.

**ROBERT A. SCHUTEMAN**

Chairman, National Association for Foreign Student Affairs.

Consultant, Workshop on the Admissions and Placement of Students from Latin  
America and Puerto Rico.

College Entrance Examination Board Grant.

**IRWIN W. SIZER**

Trustee and Board of Governors, Rutgers, The State University.

Trustee, Boston Biomedical Research Foundation.

Fellow, American Institute of Chemistry.

**JULIUS A. STRATTON**

Silver Stein Award, Massachusetts Institute of Technology Alumni Center of  
New York.

Man of the Year, National Fisheries Institute.

Bronze Beaver, Massachusetts Institute of Technology Alumni Association.

Special Commendation for 1969, Marine Technology Society.

### MEDICAL

**WILLIAM L. CURWEN**

Secretary, New England Dermatological Society.

**RICHARD L. LEHMAN**

Visiting Biologist, American Institute of Biological Sciences.

**JOHN V. PIKULA**

Surgeon-in-chief, Massachusetts Institute of Technology.

Associate Director, Harvard Surgical Unit, Boston City Hospital.

PROFESSIONAL HONORS AND ACTIVITIES

OTHER DEPARTMENTS AND LABORATORIES

CHARLES J. BATTERMAN

Member, Rules Committee, National Collegiate Athletic Association.

ALAN R. BENENFELD

Chairman, New England Chapter, American Society for Information Science.

LAWRENCE G. RUBIN

Member, Board of Editors, *Review of Scientific Instruments*.

CHARLES H. STEVENS

Consultation Officer, Special Libraries Association.

Member, President's Committee on Association Goals, Special Libraries Association.

INSTRUMENTATION LABORATORY

FREDERICK D. BROWNE

Second Vice President, Western Middlesex Chapter, Massachusetts Society of Professional Engineers.

CHARLES S. DRAPER

Public Service Award, National Aeronautics and Space Administration.

LINCOLN LABORATORY

MARIO D. BANUS

Councillor, Boston Section, Electrochemical Society.

STEVEN L. BERNSTEIN

Chairman, Boston Section, Professional Group on Communication Technology, Institute of Electrical and Electronic Engineers.

ROBERT F. BREBRICK JR.

Fellow, American Institute of Chemists.

JACK CAPON

Chairman, Boston Section, Professional Group on Information Theory, Institute of Electrical and Electronic Engineers.

LEE P. FARNSWORTH

Member, Board of Directors, Massachusetts Radiological Defense Officers Society.

GERARD A. GALLAGHER JR.

Vice President and Chairman, Education Committee, Boston Chapter, Institute of Environmental Sciences.

IRVING GOLDBERG

National Vice President, Property Administration Association.

JOHN B. GOODENOUGH

Member, Steering Committee, International Conference on Magnetism and Magnetic Materials.

Program Chairman, Magnetism School, Chania, Crete.

CNRS Research Fellow, University of Bordeaux.

Member, Program Committee, IBM Conference on Magnetic Semiconductors.

EDWARD G. GOULART

Chairman, Boston Chapter, American Society for Industrial Security.

THEODORE C. HARMAN

Assistant Treasurer, Electronic Materials Committee, Institute of Metals Division, American Institute of Mining, Metallurgical, and Petroleum Engineers.

HAROLD L. KASNITZ

Member, Board of Governors, Society of Photo-Optical Instrumentation Engineers.

Program Chairman, Symposium on Pattern Recognition Studies.

Program Chairman and Publications Vice President, 14th Annual Technical Symposium.

## HONORS AND AWARDS

**WADE M. KORNEGAY**

Honorary Doctor of Science, Lowell Technological Institute.

**RICHARD T. LACOSS**

Member, Administrative Committee, Professional Group on Geoscience Electronics, Institute of Electrical and Electronic Engineers.

Award for best paper published in *Transactions on Geoscience Electronics*, Institute of Electrical and Electronics Engineers.

**J. J. GERALD MCCUE**

Editor, *Institute of Electrical and Electronics Engineers Spectrum*.

Member, Editorial Board, *Institute of Electrical and Electronics Engineers Proceedings*.

Member, Publications Board, Institute of Electrical and Electronic Engineers.

**MARION L. MEEKS**

Secretary, U.S. Commission V (Radio Astronomy), International Scientific Radio Union.

**JACK L. MITCHELL**

Member, Technical Program Committee, American Federation of Information Processing Societies.

**LOYD R. RATHBUN**

Member, Board of Directors, Special Libraries Association.

**JOHN RHEINSTEIN**

Award for best paper published in *Transactions on Antennas and Propagation*, Institute of Electrical and Electronics Engineers.

**LEON J. RICARDI**

Guest Editor, July 1969, *Transactions on Antennas and Propagation*, Institute of Electrical and Electronics Engineers.

**MILTON L. ROSENTHAL**

President, Western Middlesex Chapter, and Director, State Board, Massachusetts Society of Professional Engineers.

**HERBERT SHERMAN**

Consultant in Electrical Engineering, Department of Medicine, Beth Israel Hospital.

**DAVID L. SPEARS**

1969 Lark-Horovitz Prize, Physics Department, Purdue University.

**ERNEST STERN**

Member, Administrative Committee, Professional Group on Ultrasonics, Institute of Electrical and Electronics Engineers.

Session Chairman, NEREM 1968; Institute of Electrical and Electronics Engineers Convention, New York; Microwave Symposium, Dallas.

**BRUCE K. WILLARD**

Treasurer, Boston Chapter, National Association of Accountants.

Certificate of Merit for Excellence in Manuscripts, National Association of Accountants.

**JOEL M. WINETT**

Chairman, SHARE CP/CMS Committee, Interactive Systems Project.