

MIT Briefing Book

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MIT Briefing Book

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Massachusetts Institute of Technology



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MIT Washington Office

The MIT Washington Office was established in 1991 to provide a presence in the nation's capital for MIT, one of the country's premier academic institutions with a long history of contributing to U.S. leadership in science and technology. A part of the MIT President's Office, the Washington Office works closely with the Institute's senior leaders to develop and advance policy positions on R&D and education issues. The office also supports major MIT initiatives in areas where national policy is being developed, currently including advanced manufacturing and the innovation ecosystem; the convergence of the life, engineering and physical sciences; energy; the environment; and innovative educational technologies. MIT students work with the Washington Office to gain hands-on experience in the science and technology policy-making process.

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Section 1

Facts and History

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Facts and History

The Massachusetts Institute of Technology is one of the world's preeminent research universities, dedicated to advancing knowledge and educating students in science, technology, and other areas of scholarship that will best serve the nation and the world. It is known for rigorous academic programs, cutting-edge research, a diverse campus community, and its long-standing commitment to working with the public and private sectors to bring new knowledge to bear on the world's great challenges.

William Barton Rogers, the Institute's founding president, believed that education should be both broad and useful, enabling students to participate in "the humane culture of the community" and to discover and apply knowledge for the benefit of society. His emphasis on "learning by doing," on combining liberal and professional education, and on the value of useful knowledge continues to be at the heart of MIT's educational mission.



MIT's founder, William Barton Rogers, 1879
Courtesy MIT Museum

MIT's commitment to innovation has led to a host of scientific breakthroughs and technological advances. Achievements of the Institute's faculty and graduates have included the first chemical synthesis of penicillin and vitamin A, the development of inertial guidance systems, modern technologies for artificial limbs, and the magnetic core memory that enabled the development of digital computers. Exciting areas of research and education today include neuroscience and the study of the brain and mind, bioengineering, energy, the environment and sustainable development, information sciences and technology, new media, financial technology, and entrepreneurship.

University research is one of the mainsprings of growth in an economy that is increasingly defined by technology. A study released by MIT in December 2015 estimated that MIT graduates had founded at least 30,000 active companies. These firms employed approximately 4.6 million people, and generated annual world sales of \$1.9 trillion, or the equivalent of the tenth-largest economy in the world in 2014.

MIT has forged educational and research collaborations with universities, governments, and companies throughout the world, and draws its faculty and students from every corner of the globe. The result is a vigorous mix of people, ideas, and programs dedicated to enhancing the world's well-being.

Fields of Study

MIT supports a large variety of fields of study, from science and engineering to the arts. MIT's five academic schools are organized into departments and other degree-granting programs. In addition, several programs, laboratories, and centers cross traditional boundaries and encourage creative thought and research.

School of Architecture and Planning

Architecture
Media Arts and Sciences
Urban Studies and Planning
Center for Real Estate

School of Engineering

Aeronautics and Astronautics
Biological Engineering
Chemical Engineering
Civil and Environmental Engineering
Data, Systems, and Society
Electrical Engineering and Computer Science
Materials Science and Engineering
Mechanical Engineering
Nuclear Science and Engineering

School of Humanities, Arts, and Social Sciences

Anthropology
Comparative Media Studies/Writing
Economics
Global Studies and Languages
History
Linguistics and Philosophy
Literature
Music and Theatre Arts
Political Science
Science, Technology, and Society

Sloan School of Management Management

School of Science

Biology
Brain and Cognitive Sciences
Chemistry
Earth, Atmospheric and Planetary Sciences
Mathematics
Physics

Interdisciplinary Undergraduate Programs

Computer Science and Molecular Biology
Humanities
Humanities and Engineering
Humanities and Science
Mathematical Economics

Interdisciplinary Graduate Programs

Computation for Design and Optimization
Computational and Systems Biology
Computational Science and Engineering
Computer Science and Molecular Biology
Design and Management (Integrated Design and Management & System Design and Management)
Harvard-MIT Health Sciences and Technology Program
Joint Program with Woods Hole Oceanographic Institution
Leaders for Global Operations
Microbiology
Operations Research
Polymers and Soft Matter
Supply Chain Management
Social and Engineering Systems
Technology and Policy
Transportation

Digital Learning

Practically since the advent of digital computing, MIT has been at the forefront of innovation in educational technology, whether through individual faculty initiatives, departmental projects, or Institute-wide programs. Literally hundreds of technology projects, each building on the lessons of those before, have helped to change the face of education at MIT and throughout the global academic community.

But in the last few years, technology-enabled change in how we teach and learn has been accelerating. We have seen remarkable educational experiments throughout higher education that are resulting in unprecedented breakthroughs:

- **New pedagogies.** Digital learning technologies enable students to do more outside of the class, so that class time can focus on deeper discussion, hands-on experiments and other forms of active learning. Digital technology can deliver lecture content, provide students rapid feedback on their understanding and even adaptive hints to foster learning, and foster more active reading and discussion through annotation tools. Digital platforms can also augment understanding, via visualizations, simulations and games. These technologies provide flexibility in course delivery, allowing more modularization and enabling students to access content anytime, anywhere; this is especially helpful for students who seek to access material in courses that are not offered every year. Many MIT faculty are experimenting with these new ways of teaching and learning.
 - **Scalable teaching.** Innovative technologies such as robust learning management platforms with short videos, embedded quizzes with instant feedback, student-ranked questions that prioritize topical focus for instructors, automated grading and assessment, discussion forums, personalization, etc. make it possible to increase student cohort size from tens or hundreds in a campus classroom to tens of thousands around
- the globe via the Internet. MITx in partnership with edX—originally an MIT-Harvard alliance, which has since expanded to include many top-tier universities worldwide—brings MIT faculty and their “MOOC” courses to many thousands of learners everywhere.
- **Open educational resources (OER).** The OER movement, pioneered in large part by MIT’s OpenCourseWare project—and since joined by hundreds more institutions worldwide—lowers financial, geographical, and political barriers to accessing quality educational content.
 - **Learning analytics and educational data mining.** Online learning systems have the ability to amass huge volumes of data on student use, navigation, and assessment as they work their way through courses. In the aggregate, these data can be used to model student learning approaches and performance. So, for example, it is now possible to monitor and predict students’ learning performance and spot potential issues early so that automated or instructor-initiated interventions can be provided. MIT faculty and other collaborators use these data for educational research to advance understanding of how people learn and identify effective pedagogical strategies.
 - **Online software innovations.** New tools such as internet labs, gaming, MIT STAR (Software Tools for Academics and Researchers), and other resources provide adaptive learning aids that present educational materials according to students’ varying needs and learning styles. MIT faculty have conceived and implemented many teaching tools, simulations, and learning aids. One remarkable example: iLabs enriches science and engineering education by enabling students to use real instruments via remote online laboratories. Unlike conventional laboratories, iLabs can be shared via the Internet, delivering the educational benefits of hands-on experimentation both to our own students and to students around the world.

In 2012, MIT established the Office of Digital Learning to harness the Institute's educational technology resources to ensure that MIT remains at the forefront of developments like these. ODL integrates formerly independent organizational units related to digital learning to focus on these strategic priorities:

- Support MIT faculty and students in bold experiments to enhance our residential education and provide resources for those who are interested in exploring how they might do so.
- Facilitate research on how people learn and on new technologies that might improve understanding, retention and application.
- Provide platforms for technological advances in digital education.
- Partner with companies, universities, governments and organizations that wish to develop new learning capabilities and enhance the competencies of their workforce, students and citizens.
- Extend MIT's knowledge and classrooms to the world.

<http://odl.mit.edu/>

Research Laboratories, Centers, and Programs

In addition to teaching and conducting research within their departments, faculty, students, and staff work in laboratories, centers, and programs.

Some of these include:

Abdul Latif Jameel Poverty Action Lab
Center for Archaeological Materials
Center for Collective Intelligence
Center for Computational Engineering
Center for Computational Research in Economics and Management Science
Center for Energy and Environmental Policy Research
Center for Environmental Health Sciences
Center for Global Change Science
Center for International Studies
Center for Materials Science and Engineering

Center for Transportation and Logistics
Clinical Research Center
Computer Science and Artificial Intelligence Laboratory
Concrete Sustainability Hub
Deshpande Center for Technological Innovation
Division of Comparative Medicine
Haystack Observatory
Initiative on the Digital Economy
Institute for Medical Engineering and Science
Institute for Soldier Nanotechnologies
Institute for Work and Employment Research
Joint Program on the Science and Policy of Global Change
Knight Science Journalism Program
Koch Institute for Integrative Cancer Research
Laboratory for Financial Engineering
Laboratory for Information and Decision Systems
Laboratory for Manufacturing and Productivity
Laboratory for Nuclear Science
Legatum Center for Development and Entrepreneurship
Martin Trust Center for MIT Entrepreneurship
Materials Processing Center
McGovern Institute for Brain Research
Media Lab
Microsystems Technology Laboratories
MIT Center for Art, Science, and Technology
MIT Energy Initiative
MIT Environmental Solutions Initiative
MIT Innovation Initiative
MIT Kavli Institute for Astrophysics and Space Research
MIT Professional Education
MIT Program in Art, Culture and Technology
MIT Sea Grant
Nuclear Reactor Laboratory
Operations Research Center
Picower Institute for Learning and Memory
Plasma Science and Fusion Center
Research Laboratory of Electronics
Simons Center for the Social Brain
Sociotechnical Systems Research Center
Transportation@MIT
Women's and Gender Studies Program

<http://web.mit.edu/research/>

Academic and Research Affiliations

Collaborative Partnership

edX

A not-for-profit enterprise of its founding partners Harvard University and the Massachusetts Institute of Technology, edX is focused on transforming online and on-campus learning through groundbreaking methodologies, game-like experiences, and cutting-edge research on an open source platform.

Idaho National Laboratory

The Idaho National Laboratory (INL) is dedicated to supporting the U.S. Department of Energy's missions in nuclear and energy research, science, and national defense. The INL established a National Universities Consortium (NUC) of universities from around the nation to engage in collaborative research in the nation's strategic nuclear energy objectives. The NUC consists of MIT, Oregon State University, North Carolina State University, The Ohio State University, and University of New Mexico.

<https://www.inl.gov/inl-initiatives/education/nuc/>

Magellan Project

The Magellan Project is a five-university partnership that constructed, and now operates, two 6.5-meter optical telescopes at the Las Campanas Observatory in Chile. The telescopes allow researchers to observe planets orbiting stars in solar systems beyond our own and to explore the first galaxies that formed near the edge of the observable universe. Collaborating with MIT on the Magellan Project are Carnegie Institute of Washington, Harvard University, University of Arizona, and University of Michigan.

Massachusetts Green High Performance Computing Center

The Massachusetts Green High Performance Computing Center (MGHPCC) is a collaboration of five of the state's most research-intensive universities—Boston University, Harvard University, MIT, Northeastern University, and the University of Massachusetts—the Commonwealth of Massachusetts, CISCO, and EMC. The MGHPCC is a datacenter dedicated to providing the growing research computing capacity needed to support breakthroughs in science.

<http://www.mghpcc.org/>

MIT and Masdar Institute Cooperative Program

A collaboration between MIT and the government of Abu Dhabi to establish a graduate research university focused on alternative energy, sustainability, and advanced technology. The MIT and Masdar Institute Cooperative Program supports Abu Dhabi's goal of developing human capital for a diversified knowledge-based economy. See page 105 for more information.

Northeast Radio Observatory Corporation

The Northeast Radio Observatory Corporation (NEROC) is a nonprofit consortium of educational and research institutions that was formed in 1967 to plan an advanced radio and radar research facility in the Northeast. NEROC consists of nine educational and research institutions, these are MIT, Boston University, Brandeis University, Dartmouth College, Harvard University, Harvard-Smithsonian Center for Astrophysics, University of Massachusetts, University of New Hampshire, and Wellesley College.

<http://www.haystack.mit.edu/hay/neroc.html>

Singapore-MIT Alliance for Research and Technology Centre

The Singapore-MIT Alliance for Research and Technology (SMART) Centre is a major research enterprise established by MIT in partnership with the National Research Foundation of Singapore. The SMART Centre serves as an intellectual hub for research interactions between MIT and Singapore at the frontiers of science and technology. See page 102 for more information about SMART.

<http://smart.mit.edu/>

MIT Skoltech Initiative

The MIT Skoltech Initiative is a multi-year collaboration between the Skolkovo Foundation, the Skolkovo Institute of Science and Technology (Skoltech), and MIT to help conceive and launch a new private graduate research university focused on a small number of key global themes and designed to stimulate the development of a robust and economically impactful innovation ecosystem in Russia. See page 102 for more information.

Synthetic Biology Engineering Research Center

The Synthetic Biology Engineering Research Center (Synberc) is a multi-institution research effort to lay the foundation for synthetic biology. The core universities partners are MIT, University of California at Berkeley, University of California at San Francisco, Harvard University, and Stanford University. Synberc foundational research will be motivated by pressing biotechnology applications.

<http://synberc.org/>

Major Collaborator

Broad Institute

The Broad Institute seeks to transform medicine by empowering creative and energetic scientists of all disciplines from across the MIT, Harvard, and Harvard-affiliated hospital communities to work together to address even the most difficult challenges in biomedical research. The Broad Institute was founded in 2003; Eli and Edythe Broad, MIT, and Harvard University were founding partners.

<http://www.broadinstitute.org/>

Charles Stark Draper Laboratory

Founded as MIT's Instrumentation Laboratory, Draper Laboratory separated from MIT in 1973 to become an independent not-for-profit research and educational organization. Much of Draper's current research and development focuses on problems that arise in the measurement, analysis, simulation, and control of complex dynamic systems. This research and development covers a wide range of application areas, including guidance, navigation and control, microsystems, complex reliable systems, autonomous systems, information and decision systems, biomedical and chemical systems, secure networking and communications, energy systems, and commercial space systems.

<http://www.draper.com/>

Howard Hughes Medical Institute

The Howard Hughes Medical Institute (HHMI) is a scientific and philanthropic organization that conducts biomedical research in collaboration with universities, academic medical centers, hospitals, and other research institutions throughout the country. Nineteen HHMI investigators hold faculty appointments at MIT.

<http://www.hhmi.org/>

Ragon Institute of MGH, MIT and Harvard

The Ragon Institute was established at Massachusetts General Hospital, MIT, and Harvard in February 2009. The Institute brings scientists and clinicians together with engineers in an interdisciplinary effort to better understand how the body fights infections and, ultimately, to apply that understanding against a wide range of infectious diseases and cancers. The dual mission of the Institute is to contribute to the discovery of an HIV/AIDS vaccine and the collaborative study of immunology.

<http://ragoninstitute.org/>

Whitehead Institute for Biomedical Research

The Whitehead Institute for Biomedical Research is a nonprofit, independent research institution whose research excellence is nurtured by the collaborative spirit of its faculty and the creativity and dedication of its graduate students and postdoctoral scientists. Whitehead's primary focus is basic science, with an emphasis on molecular and cell biology, genetics and genomics, and developmental biology. Specific areas of inquiry at Whitehead include cancer, transgenic science, stem cells, regenerative biology, genetics, genomics, membrane biology, vertebrate development, and neurological disorders. Whitehead is affiliated with MIT through its members, who hold faculty positions at MIT. A small number of junior investigators also hold positions at Whitehead Institute as part of the Whitehead Fellows program.

<http://wi.mit.edu/>

Other Affiliation

MIT-Woods Hole Oceanographic Institution Joint Program in Oceanography and Applied Ocean Science and Engineering

The Woods Hole Oceanographic Institution (WHOI) is the largest independent oceanographic institution in the world. The MIT/WHOI Joint Program provides a high quality doctoral education leading to an internationally-recognized Ph.D. degree awarded by both institutions. The Joint Program is organized within five sub-disciplinary areas, each administered by a Joint Committee consisting of MIT faculty and WHOI scientists: Applied Ocean Science and Engineering, Biological Oceanography, Chemical Oceanography, Marine Geology and Geophysics, and Physical Oceanography.

<http://mit.who.edu/>

Naval Construction and Engineering

The graduate program in Naval Construction and Engineering (Course 2N) is intended for active duty officers in the U.S. Navy, U.S. Coast Guard, and foreign Navies who have been designated for specialization in the design, construction, and repair of naval ships. The curriculum prepares Navy, Coast Guard, and foreign officers for careers in ship design and construction and is sponsored by Commander, Naval Sea Systems Command. Besides providing the officers a comprehensive education in naval engineering, the program emphasizes their future roles as advocates for innovation in ship design and acquisition.

<http://web.mit.edu/2n/>

Reserve Officer Training Corps Programs

Military training has existed at MIT since students first arrived in 1865. In 1917, MIT established the nation's first Army Reserve Officer Training Corps (ROTC) unit. Today, Air Force, Army, and Naval ROTC units are based at MIT. These programs enable students to become commissioned military officers upon graduation. More than 12,000 officers have been commissioned from MIT, and more than 150 have achieved the rank of general or admiral.

<https://due.mit.edu/rotc/rotc-programs/>

Study at Other Institutions

MIT has cross-registration arrangements with several area schools. At the undergraduate level, students may cross-register at Harvard University, Wellesley College, Massachusetts College of Art and Design, and the School of the Museum of Fine Arts. At the graduate level, qualified students may enroll in courses at Harvard University, Wellesley College, Boston University, Brandeis University, and Tufts University. International study opportunities including the Cambridge-MIT Exchange, departmental exchanges, and the MIT-Madrid Program are described on page 107.

Education Highlights

MIT has long maintained that professional competence is best fostered by coupling teaching with research and by focusing education on practical problems. This hands-on approach has made MIT a consistent leader in outside surveys of the nation's best colleges. MIT was the first university in the country to offer curriculums in architecture (1865), electrical engineering (1882), sanitary engineering (1889), naval architecture and marine engineering (1895), aeronautical engineering (1914), meteorology (1928), nuclear physics (1935), and artificial intelligence (1960s). More than 4,000 MIT graduates are professors at colleges and universities around the world. MIT faculty have written some of the best-selling textbooks of all time, such as *Economics* by Paul A. Samuelson and *Calculus and Analytic Geometry* by George Thomas. The following are some notable MIT teaching milestones since 1968.

1968 MIT and Woods Hole Oceanographic Institute create a joint program for graduate studies in oceanography. This is the first higher education partnership of its kind.

1969 MIT launches the Undergraduate Research Opportunities Program (UROP), the first of its kind. The program, which enables undergraduates to work directly with faculty on professional research, subsequently is copied in universities throughout the world.

1970 The Harvard-MIT Program in Health Sciences and Technology is established to focus advances in science and technology on human health and to train physicians with a strong base in engineering and science.

1970 Department of Mechanical Engineering initiates the course 2.70 (now 2.007) design contest, created by professor Woodie C. Flowers. The competition was to build a mechanical device, out of a set of relatively simple wooden and metal parts, that would roll down a ramp at a precisely controlled rate.

1971 MIT holds its first Independent Activities Period (IAP), a January program that emphasizes creativity and flexibility in teaching and learning.

1974 The Minority Introduction to Engineering and Science (MITES) program is established to provide a rigorous six-week residential, academic summer program for promising high school juniors who are interested in careers in science and engineering.

1977 Whitaker College of Health Sciences, Technology, and Management is established to strengthen MIT's ability to engage in health related research and education.

1977 MIT organizes the Program in Science, Technology, and Society to explore and teach courses on the social context and consequences of science and technology—one of the first programs of its kind in the United States.

1981 MIT-Japan Program is created to send MIT students to Japan for internships. In 1994, the program becomes part of the MIT International Science and Technology Initiatives (MISTI). Today, the program also fosters research collaboration between faculty at MIT and in Asia through the MISTI Hayashi Seed Fund.

1981 MIT launches Project Athena, a \$70 million program to explore the use of computers in education. Digital Equipment Corporation and IBM each contribute \$25 million in computer equipment.

1981 The MIT Sloan School of Management launches its Management of Technology program, the world's first master's program to focus on the strategic management of technology and innovation.

1983 MIT establishes the Center for Real Estate and the first Master of Science in Real Estate Development (MSRED) degree program in the U.S.

1983–1990 MIT language and computer science faculty join in the Athena Language Learning Project to develop interactive videos that immerse students in the language and character of other cultures. The work pioneers a new generation of language learning tools.

1984 MIT establishes the Media Laboratory, bringing together pioneering educational programs in computer music, film, graphics, holography, lasers, and other media technologies.

1990 MIT initiates an artist-in-residence program to provide students with opportunities to interact with nationally and internationally recognized artists through master classes, lecture-demonstrations, performances and workshops.

1991 The Department of Mechanical Engineering's course 2.70 (2.007) design contest goes international, with students competing from Japan, England and Germany.

1992 MIT establishes the MacVicar Faculty Fellows Program, named in honor of the late Margaret A. MacVicar, to recognize outstanding contributions to teaching. MacVicar, a professor of physics, had conceived of, designed, and launched UROP (see 1969, above).

1992 MIT launches the Laboratory for Advanced Technology in the Humanities to extend its pioneering work in computer- and video-assisted language learning to other disciplines. Its first venture was a text and performance multimedia archive for studies of Shakespeare's plays.

1992 MIT Faculty approves the M.Eng. program in Electrical Engineering and Computer Science, an integrated five-year program leading to the simultaneous award of a bachelor's and a master's degree.

1993 In recognition of the increasing importance of molecular and cell biology, MIT becomes the first college in the nation to add biology to its undergraduate requirement.

1994 The MIT International Science and Technology Initiatives (MISTI) are created to connect MIT students to internships and research around the world. MIT's primary international program, MISTI is a pioneer in applied international studies—a distinctively MIT concept.

1994 The MIT-China Program is created within MISTI to send MIT students to China for internships.

1995 The School of Engineering and the Sloan School of Management join to create a graduate program in system design and management (SDM), in which students can complete most course requirements at their job sites through interactive distance-learning.

1995 MIT's Political Science Department establishes the Washington Summer Internship Program to provide undergraduates the opportunity to apply their scientific and technical training to public policy issues.

1997 The MIT-Germany Program is created within MISTI to send MIT students to Germany for internships.

1998 MIT teams up with Singapore's two leading research universities to create a global model for long-distance engineering education and research. This large-scale experiment, the first truly global collaboration in graduate engineering education and research, is a model for today's distance education.

1998 MIT-India Program is created within MISTI to send MIT students to India for internships.

1998 The Division of Bioengineering & Environmental Health (BEH) begins operation with the mission of fostering MIT education and research fusing engineering with biology.

1998 The School of Engineering establishes the Engineering Systems Division (ESD), focused on the development of new approaches, frameworks, and theories to better understand engineering systems behavior and design.

1999 MIT-Italy Program is created within MISTI to send MIT students to Italy for internships.

1999 The University of Cambridge and MIT establish the Cambridge-MIT Institute, whose programs include student and faculty exchanges, an integrated research program, professional practice education, and a national competitiveness network in Britain.

1999 MIT establishes the Society of Presidential Fellows to honor the most outstanding students worldwide entering the Institute's graduate programs. With gifts provided by lead donors, presidential fellows are awarded fellowships that fund first year tuition and living expenses.

2000 MIT Faculty approve the Communication Requirement (CR), which went into effect for the Class of 2005. The CR integrates substantial instruction and practice in writing and speaking into all four years and across all parts of MIT's undergraduate program. Students participate regularly in activities designed to develop both general and technical communication skills.

2001 Studio Physics is introduced to teach freshman physics. Incorporating a highly collaborative, hands-on environment that uses networked laptops and desktop experiments, the new curriculum lets students work directly with complicated and unfamiliar concepts as their professors introduce them.

2001 MIT launches OpenCourseWare, a program that makes materials for nearly all of its courses freely available on the web and serves as a model for sharing knowledge to benefit all humankind.

2001 The MIT-France Program is created within MISTI to send MIT students to France for internships and enhance research collaboration between faculty at MIT and in France through the MIT-France Seed Fund.

2001 MIT establishes WebLab, a microelectronics teaching laboratory that allows students to interact remotely on the Web with transistors and other microelectronics devices anywhere and at any time.

2001 MIT's Earth System Initiative launches TerraScope, a freshman course in which students work in teams to solve complex earth sciences problems. Bringing together physics, mathematics, chemistry, biology, management, and communications, the course has enabled students to devise strategies for preserving tropical rainforests, understand the costs and the benefits of oil drilling in the Arctic National Wildlife Refuge, and plan a mission to Mars.

2002 To give engineering students the opportunity to develop the skills they'll need to be leaders in the workplace, MIT introduces the Undergraduate Practice Opportunities Program (UPOP). The program involves a corporate training workshop, job seminars taught by alumni, and a 10-week summer internship.

2003 MIT Libraries introduce DSpace, a digital repository that gathers, stores, and preserves the intellectual output of MIT's faculty and research staff, and makes it freely available to research institutions worldwide. Within a year of its launch, DSpace material had been downloaded more than 8,000 times, and more than 100 organizations had adopted the system for their own use.

2003 MIT's Program in Computational and Systems Biology (CSBi), an Institute-wide program linking biology, engineering, and computer science in a systems biology approach to the study of cell-to-cell signaling, tissue formation, and cancer, begins accepting students for a new Ph.D. program that will give them the tools for treating biological entities as complex living systems.

2004 The MIT-Mexico Program is created within MISTI to send MIT students to Mexico for internships.

2005 Combining courses from engineering, mathematics, and management, MIT launches its master's program in Computation for Design and Optimization, one of the first curriculums in the country to focus on the computational modeling and design of complex engineered systems. The program prepares engineers for the challenges of making systems ranging from computational biology to airline scheduling to telecommunications design and operations run with maximum effectiveness and efficiency.

2006 MIT creates the Campaign for Students, a fundraising effort dedicated to enhancing the educational experience at MIT through creating scholarships and fellowships, and supporting multidisciplinary education and student life.

2006 The MIT-Spain Program is created within MISTI to send MIT students to Spain for internships.

2007 MIT makes material from virtually all MIT courses available online for free on OpenCourseWare. The publication marks the beginning of a worldwide movement toward open education that now involves more than 160 universities and 5,000 courses.

2008 The MIT-Israel Program is created within MISTI to train and send MIT students to Israel for internships; strengthen collaborations between MIT and Israel; and organize workshops, conferences, symposia and lectures at MIT and in Israel.

2009 MIT launches the Bernard M. Gordon-MIT Engineering Leadership Program. Through interaction with industry leaders, faculty, and fellow students, the program aims to help undergraduate engineering students develop the skills, tools, and character they will need as future engineering leaders.

2009 The MIT-Brazil Program is created within MISTI to send MIT students to Brazil for internships and encourage research collaboration between faculty at MIT and in Brazil through the MIT-Brazil Seed Fund.

2009 MIT introduces a minor in energy studies, open to all undergraduates. The new minor, unlike most energy concentrations available at other institutions, and unlike any other concentration at MIT, is designed to be inherently cross-disciplinary, encompassing all of MIT's five schools. It can be combined with any major subject. The minor aims to allow students to develop expertise and depth in their major disciplines, but then complement that with the breadth of understanding offered by the energy minor.

2010 MIT introduces the flexible engineering degree for undergraduates. The degree, the first of its kind, allows students to complement a deep disciplinary core with an additional subject concentration. The additional concentration can be broad and interdisciplinary in nature (energy, transportation, or the environment), or focused on areas that can be applied to multiple fields (robotics and controls, computational engineering, or engineering management).

2011 MIT announces MITx, an online learning initiative that will offer a portfolio of free MIT courses through an online interactive learning platform. The Institute expects the platform to enhance the educational experience of its on-campus students and serve as a host for a virtual community of millions of learners around the world. The MITx prototype course—6.002x or "Circuits and Electronics"—debuts in March 2012 with almost 155,000 people registering for the course.

2012 MIT establishes the Office of Digital Learning to harness the Institute’s digital learning resources, creating more integration and coordination among formerly independent organizational units related to educational technology.

2012 MIT and Harvard University announce edX, a transformational new partnership in online education. Through edX, the two institutions will collaborate to enhance campus-based teaching and learning and build a global community of online learners. An open-source technology platform will deliver online courses that move beyond the standard model of online education that relies on watching video content and will offer an interactive experience for students. The University of California at Berkeley later joins edX. The three institutions offer the first edX courses in fall 2012.

2012 Lincoln Laboratory debuts a new outreach program—a two-week summer residential program for high-school students. The program, Lincoln Laboratory Radar Introduction for Student Engineers, focuses on radar technology. The project-based curriculum is based on a popular class offered during MIT’s Independent Activities Period (IAP) and taught by Laboratory technical staff. While the instructors adapted the IAP course to suit high-school students, they retained the challenging nature of the original class. The goal of the program is that students take away not only an understanding of radar systems but also the realization that engineering is about problem-solving and applying knowledge in innovative ways.

2012 MIT announces the launch of the Institute for Medical Engineering and Science (IMES). IMES brings together research and education efforts at the nexus of engineering, science, and clinical medicine to advance human health.

2013 The School of Engineering and Lincoln Laboratory launch Beaver Works. This initiative facilitates project-based learning by leveraging partnerships between faculty and students at MIT and practicing engineers at Lincoln Laboratory to promote collaborative research and to enable the fabrication of prototype systems. The initiative’s signature collaboration is the Beaver Works capstone project in areas such as unmanned aerial vehicles, small satellites, autonomous underwater systems, energy systems, cybersecurity, communications, big data analytics, and advanced devices.

2013 OCW inaugurates “OCW Educator” with the first “This Course at MIT” page. This feature offers educational ideas, practices, and pedagogical expertise from MIT faculty in order to inspire teachers around the world with innovations that they may use in their own teaching.

2014 MITx on edX registers its one-millionth learner on May 27, 2014.

2014 The Office of Digital Learning pilots the MITx Global Entrepreneurship Bootcamp, an innovative “blended learning” program that combines online education with an intensive, immersive one-week on-campus experience.

2014 MIT Professional Education, in cooperation with the Office of Digital Learning and edX, begins offering online courses designed specifically for industry and active professionals. Based on research in areas ranging from big data, cybersecurity, and entrepreneurship, these courses enable MIT to disseminate knowledge at scale to professionals around the world, in areas critical to industry. The first course on big data enrolled more than 7,000 paid enrollees from over 100 countries.

2015 SuperUROP, an amplified version of the Undergraduate Research Opportunities Program, is launched in the School of Engineering. First conceived and implemented in 2012 under the leadership of the Department of Electrical Engineering and Computer Science, SuperUROP is a year-long program that enables students to tackle complex problems and affords them the time, training, resources, and guidance necessary for deep scientific and engineering inquiry.

2015 MIT creates the MIT-Woodrow Wilson Academy of Teaching and Learning to advance pre-K through 12 education by combining MIT's "mind and hand" approach to learning with recent breakthroughs in cognitive science and digital learning. The program develops STEM teachers and school leaders around the world.

2015 The Residential MITx platform hosts its 100th course. Nearly 90% of MIT undergraduates have participated in one or more courses that use the platform.

2015 The Institute for Data, Systems, and Society (IDSS) is launched. A collaboration among all five of MIT's schools, IDSS brings together researchers working in the mathematical, behavioral, and empirical sciences to capitalize on their shared interest in tackling complex societal problems.

2015 Lincoln Laboratory offered LLCipher, a one-week workshop providing an introduction to cryptography. Lessons provided high-school students the foundational knowledge to understand a math-based theoretical approach to securing data. Students constructed provably secure encryption and digital signature schemes, and then learned about zero-knowledge proofs and multiparty computation. The workshop's success warranted an expansion in future years.

Research Highlights

The following are selected research achievements of MIT faculty and staff over the last five decades.

1967 Joel Moses, William A. Martin, and others develop MACSYMA, a computer program that manipulates algebraic quantities and performs symbolic integration and differentiation.

1968 Radar-based lunar studies are performed by Lincoln Laboratory. The use of radar to map the surface of the moon becomes possible when the radar beam is made small enough to discriminate between two points on the surface that would contribute echoes at the same range and Doppler shift. Altitude data is added to the two-dimensional radar reflectivity data by the use of interferometry. In addition, from the strength of radar reflections, it is estimated that the lunar surface has weight-bearing properties similar to that of terrestrial sand.

1969 Ioannis V. Yannas begins to develop artificial skin—a material used successfully to treat burn victims.

1970 David Baltimore reports the discovery of reverse transcriptase, an enzyme that catalyzes the conversion of RNA to DNA. The advance, which led to a Nobel Prize for Baltimore in 1975, provided a new means for studying the structure and function of genes.

1972 Lincoln Laboratory's Moving Target Detector (MTD) achieved a new performance level for the detection of aircraft in the presence of radar clutter, such as ground, weather, and birds. It employed an antenna with two fan beams to provide coverage from the immediate vicinity of an airport to a distance of 60 nautical miles. The MTD became the world-recognized standard for Airport Surveillance Radar.

1973 Jerome Friedman and Henry Kendall, with Stanford colleague Richard Taylor, complete a series of experiments confirming the theory that protons and neutrons are made up of minute particles called quarks. The three receive the 1979 Nobel Prize in Physics for their work.

1974 Samuel C. C. Ting, Ulrich Becker, and Min Chen discover the "J" particle. The discovery, which earns Ting the 1976 Nobel Prize in Physics, points to the existence of one of the six postulated types of quarks.

1975 The Lincoln Laboratory Experimental Test System (ETS) becomes operational. The ETS is used for deep-space surveillance, daylight satellite tracking, searching the geostationary belt, and making astronomical measurements.

1975–1977 Barbara Liskov and her students design the CLU programming language, an object-oriented language that helps form the underpinnings for languages like Java and C++. As a result of this work and other accomplishments, Liskov later wins the Turing Award, considered the Nobel Prize in computing.

1975–1982 Joel Moses develops the first extensive computerized program (MACSYMA) able to manipulate algebraic quantities and perform symbolic integration and differentiation.

1976 H. Gobind Khorana and his research team complete chemical synthesis of the first human-manufactured gene fully functional in a living cell. The culmination of 12 years of work, it establishes the foundation for the biotechnology industry. Khorana won the 1968 Nobel Prize in Physiology/Medicine for other genetics work.

1977 Phillip Sharp discovers the split gene structure of higher organisms, changing the view of how genes arose during evolution. For this work, Sharp shared the 1993 Nobel Prize in Physiology/Medicine.

1977 Ronald Rivest, Adi Shamir, and Leonard Adleman invent the first workable public key cryptographic system. The new code, which is based on the use of very large prime numbers, allows secret communication between any pair of users. Still unbroken, the code is in widespread use today.

1979 The high frame rate required for airborne laser radar demands an array of photomixers, and Lincoln Laboratory begins a design study in binary optics for a solution. A hologram is proposed to generate an array of beams with the amplitude and phase distributions necessary to ensure efficient photomixing.

1979 Robert Weinberg reports isolating and identifying the first human oncogene—an altered gene that causes the uncontrolled cell growth that leads to cancer.

1981 Alan Guth publishes the first satisfactory model, called cosmic inflation, of the universe's development in the first 10–32 seconds after the Big Bang.

1982 Alan Davison discovers a new class of technetium compounds that leads to the development of the first diagnostic technetium drug for imaging the human heart.

1982 Lincoln Laboratory utilizes a new generation of digital signal processing chips to develop a compact linear predictive coding (LPC) vocoder small and inexpensive enough for wide distribution. A vocoder analyzes and synthesizes speech using parameters that can be encrypted and transmitted at a much lower bit rate than the original speech waveform. The LPC vocoder is important in the U.S. development of secure voice systems.

1985 Susumu Tonegawa describes the structure of the gene for the receptors—"anchor molecules"—on the white blood cells called T lymphocytes, the immune system's master cells. In 1987, Tonegawa receives the Nobel Prize in Physiology/Medicine for similar work on the immune system's B cells.

1985 The Terminal Doppler Weather Radar (TDWR) program is initiated at Lincoln Laboratory to develop an automated system for detecting weather hazards in the airport terminal area and to help pilots avoid them. A successful TDWR prototype led to the procurement of 47 TDWRs from Raytheon in the 1990s, and there has not been a major U.S. wind-shear-related accident since 1994.

1986 Stephen Benton creates the first free-standing hologram. In 1985, Benton began generating synthetic holograms from 3D digital databases, initially creating a 3D image of a green car floating in front of the Boston skyline.

1986 H. Robert Horvitz identifies the first two genes found to be responsible for the process of cell death, which is critical both for normal body development and for protection against autoimmune diseases, cancer, and other disorders. Going on to make many more pioneering discoveries about the genetics of cell death, Horvitz shares the 2002 Nobel Prize in Physiology/Medicine for his work.

1988 Project Daedalus sets distance and endurance records for human-powered aircraft in a flight over the Aegean Sea.

1988 Sallie Chisholm and associates report the discovery of a form of ocean plankton that may be the most abundant single species on earth.

1989 The Airport Surveillance Radar (ASR)-9, developed at Lincoln Laboratory, provides air traffic control (ATC) personnel with a display free of clutter and a telephone bandwidth data stream for transmitting information to ATC facilities. The technology was later transferred to Westinghouse Corporation, which deployed the ASR-9 at 137 sites in the U.S. for the Federal Aviation Administration.

1990 Julius Rebek, Jr. and associates create the first self-replicating synthetic molecule.

1990 Building on the discovery of the metathesis—the process of cutting carbon-carbon double bonds in half and constructing new ones—Richard Schrock devises a catalyst that greatly speeds up the reaction, consumes less energy, and produces less waste. A process based on his discovery is now in widespread use for efficient and more environmentally friendly production of important pharmaceuticals, fuels, synthetic fibers, and many other products. Schrock shares the 2005 Nobel Prize in Chemistry for his breakthrough.

1991 Cleveland heart doctors begin clinical trials of a laser catheter system for microsurgery on the arteries that is largely the work of Michael Feld and his MIT associates.

1992 The Lincoln Laboratory Microelectronics Laboratory becomes operational. It is a 70,000 sq ft state-of-the-art semiconductor research and fabrication facility supporting a wide range of programs: flight-quality gigapixel charge-coupled device (CCD) imager focal planes, photon-counting avalanche photodiode arrays, and niobium-based superconducting circuits, to name a few. The Microelectronics Laboratory also supports advanced packaging with a precision multichip module technology and an advanced three-dimensional circuit stacking technology.

1993 H. Robert Horvitz, together with scientists at Massachusetts General Hospital, discover an association between a gene mutation and the inherited form of amyotrophic lateral sclerosis (Lou Gehrig's disease).

1993 David Housman joins colleagues at other institutions in announcing a successful end to the long search for the genetic defect linked with Huntington's disease.

1993 Alexander Rich and postdoctoral fellow Shuguang Zhang report the discovery of a small protein fragment that spontaneously forms into membranes. This research will lead to advances in drug development, biomedical research, and the understanding of Alzheimer's and other diseases.

1993 The Traffic Alert and Collision Avoidance System (TCAS) is deployed. TCAS reduces midair collisions by sensing nearby aircraft and issuing an advisory to the pilot. Lincoln Laboratory developed the surveillance technology used by TCAS and built and flight-tested the TCAS prototype. Now mandated on all large transport aircraft, TCAS has been in operation for over a decade and has been credited with preventing several catastrophic accidents.

1994 MIT engineers develop a robot that can “learn” exercises from a physical therapist, guide a patient through them, and, for the first time, record biomedical data on the patient's condition and progress.

1995 The Advanced Land Imager (ALI) is developed at Lincoln Laboratory to validate new technologies that (1) could be utilized in future land-observing satellites and (2) would reduce mass, size, and power consumption while improving instrument sensitivity and image resolution.

1995 Scientists at the Whitehead Institute for Biomedical Research and MIT create a map of the human genome and begin the final phase of the Human Genome Project. This powerful map contains more than 15,000 distinct markers and covers virtually all of the human genome.

1996 A group of scientists at MIT's Center for Learning and Memory, led by Matthew Wilson and Nobel laureate Susumu Tonegawa, use new genetic and multiple-cell monitoring technologies to demonstrate how animals form memory about new environments.

1997 MIT physicists create the first atom laser, a device that is analogous to an optical laser but emits atoms instead of light. The resulting beam can be focused to a pinpoint or made to travel long distances with minimal spreading.

1998 MIT biologists, led by Leonard Guarente, identify a mechanism of aging in yeast cells that suggests researchers may one day be able to intervene in, and possibly inhibit, the aging process in certain human cells.

1998 Lincoln Near Earth Asteroid Research (LINEAR) is developed by Lincoln Laboratory to detect and catalogue near-Earth asteroids that may threaten Earth. Applying technology originally developed for the surveillance of Earth-orbiting satellites, LINEAR uses two ground-based electro-optical deep-space surveillance telescopes.

1998 An interdisciplinary team of MIT researchers, led by Yoel Fink and Edwin L. Thomas, invent the “perfect mirror,” which offers radical new ways of directing and manipulating light. Potential applications range from a flexible light guide that can illuminate specific internal organs during surgery to new devices for optical communications.

1999 Michael Cima, Robert Langer, and graduate student John Santini report the first microchip that can store and release chemicals on demand. Among its potential applications is a “pharmacy” that could be swallowed or implanted under the skin and programmed to deliver precise drug dosages at specific times.

1999 Alexander Rich leads a team of researchers in the discovery that left-handed DNA (also known as Z-DNA) is critical for the creation of important brain chemicals. Having first produced Z-DNA synthetically in 1979, Rich succeeds in identifying it in nature in 1981. He also discovers its first biological role and received the National Medal of Science for this pioneering work in 1995.

2000 Scientists at the Whitehead Institute/MIT Center for Genome Research and their collaborators announce the completion of the Human Genome Project. Providing about a third of all the sequences assembled, the Center was the single largest contributor to this international enterprise.

2000 Researchers develop a device that uses ultrasound to extract a number of important molecules noninvasively and painlessly through the skin. They expect that the first application will be a portable device for noninvasive glucose monitoring for diabetics.

2000 Researchers from the MIT Sloan School of Management launch the Social and Economic Explorations of Information Technology (SeeIT) Project, the first empirical study of the effects of information technology (IT) on organizational and work practices. Examining IT’s relationship to changes in these models, SeeIT provides practical data for understanding and evaluating IT’s business and economic effects, which will enable us to take full advantage of its opportunities and better control its risks.

2001 In a step toward creating energy from sunlight as plants do, Daniel Nocera and a team of researchers invent a compound that, with the help of a catalyst and energy from light, produces hydrogen.

2002 MIT researchers create the first acrobatic robotic bird—a small, highly agile helicopter for military use in mountain and urban combat.

2002–2005 Scientists at MIT, the Whitehead Institute for Biomedical Research, and the Broad Institute complete the genomes of the mouse, the dog, and four strains of phytoplankton, photosynthetic organisms that are critical for the regulation of atmospheric carbon dioxide. They also identify the genes required to create a zebrafish embryo. In collaboration with scientists from other institutions, they map the genomes of chimpanzees, humans’ closest genetic relative, and the smallest known vertebrate, the puffer fish.

2003 Enhanced Regional Situation Awareness (ERSA) system is developed by Lincoln Laboratory for the U.S. Air Force to provide improved defense of the airspace surrounding the National Capital Region (NCR). ERSA capabilities have improved airspace surveillance, threat assessment and decision support, distribution of a common air picture to multiple agencies, and new ways to respond to aircraft violating the NCR airspace.

2003 MIT scientists cool a sodium gas to the lowest temperature ever recorded—a half-a-billionth of a degree above absolute zero. Studying these ultra-low temperature gases will provide valuable insights into the basic physics of matter; and by facilitating the development of better atomic clocks and sensors for gravity and rotation, they also could lead to vast improvements in precision measurements.

2004 MIT's Levitated Dipole Experiment, a collaboration among scientists at MIT and Columbia, generates a strong dipole magnetic field that enables them to experiment with plasma fusion, the source of energy that powers the sun and stars, with the goal of producing it on Earth. Because the hydrogen that fuels plasma fusion is practically limitless and the energy it produces is clean and doesn't contribute to global warming, fusion power will be of enormous benefit to humankind and to earth systems in general.

2004 A team, led by neuroscientist Mark Bear, illuminates the molecular mechanisms underlying Fragile X Syndrome and shows that it might be possible to develop drugs that treat the symptoms of this leading known inherited cause of mental retardation, whose effects range from mild learning disabilities to severe autism.

2004 Shuguang Zhang, Marc A. Baldo, and recent graduate Patrick Kiley, first figure out how to stabilize spinach proteins—which, like all plants, produce energy when exposed to light—so they can survive without water and salt. Then, they devise a way to attach them to a piece of glass coated with a thin layer of gold. The resulting spinach-based solar cell, the world's first solid-state photosynthetic solar cell, has the potential to power laptops and cell phones with sunlight.

2005 MIT physicists, led by Nobel laureate Wolfgang Ketterle, create a new type of matter, a gas of atoms that shows high-temperature superfluidity.

2005 Vladimir Bulovic and Tim Swager develop lasing sensors based on a semiconducting polymer that is able to detect the presence of TNT vapor subparts per billion concentrations.

2006 MIT launches the MIT Energy Initiative (MITEI) to address world energy problems. Led by Ernest J. Moniz and Robert C. Armstrong, MITEI coordinates energy research, education, campus energy management, and outreach activities across the Institute.

2007 Rudolf Jaenisch, of the Whitehead Institute for Biomedical Research, conducts the first proof-of-principle experiment of the therapeutic potential of induced pluripotent stem cells (iPS cells), using iPS cells reprogrammed from mouse skin cells to cure a mouse model of human sickle-cell anemia. Jaenisch would then use a similar approach to treat a model of Parkinson's disease in rats.

2007 Marin Soljačić and his colleagues develop a new form of wireless power transmission they call WITricity. It is based on a strongly coupled magnetic resonance and can be used to transfer power over distances of a few meters with high efficiency. The technique could be used commercially to wirelessly power laptops, cell phones, and other devices.

2007 David H. Koch '62, SM '63 gives MIT \$100 million to create the David H. Koch Institute for Integrative Cancer Research. The Koch Institute opens in 2011. It brings together molecular geneticists, cell biologists, and engineers in a unique multi-disciplinary approach to cancer research.

2007 Tim Jamison discovers that cascades of epoxide-opening reactions that were long thought to be impossible can very rapidly assemble the Red Tide marine toxins when they are induced by water. Such processes may be emulating how these toxins are made in nature and may lead to a better understanding of what causes devastating Red Tide phenomena. These methods also open up an environmentally green synthesis of new classes of complex highly biologically active compounds.

2007 MIT mathematicians form part of a group of 18 mathematicians from the U.S. and Europe that maps one of the most complicated structures ever studied: the exceptional Lie group E8. The "answer" to the calculation, if written, would cover an area the size of Manhattan. The resulting atlas has applications in the fields of string theory and geometry.

2008 Mriganka Sur's laboratory discovers that astrocytes, star-shaped cells in the brain that are as numerous as neurons, form the basis for functioning brain imaging. Using ultra high-resolution imaging in the intact brain, they demonstrate that astrocytes regulate blood flow to active brain regions by linking neurons to brain capillaries.

2008 A team, led by Marc A. Baldo, designs a solar concentrator that focuses light at the edges of a solar power cell. The technology can increase the efficiency of solar panels by up to 50 percent, substantially reducing the cost of generating solar electricity.

2008 Daniel Nocera creates a chemical catalyst that hurdles one of the obstacles to widespread use of solar power—the difficulty of storing energy from the sun. The catalyst, which is cheap and easy to make, uses the energy from sunlight to separate the hydrogen and oxygen molecules in water. The hydrogen can then be burned, or used to power an electric fuel cell.

2009 Lincoln Laboratory develops and demonstrates the Lincoln Distributed Disaster Response System, which enables information from airborne platforms, distributed weather stations, GPS-enabled devices, and other sources to be shared by responders at the emergency command centers and by those equipped with ruggedized laptops at the front lines. The system design initially focuses on fighting a large-scale fire but is also applicable for any large-scale disaster response.

2009 A team of MIT researchers, led by Angela Belcher, reports that it is able to genetically engineer viruses to produce both the positively and negatively charged ends of a lithium-ion battery. The battery has the same energy capacity as those being considered for use in hybrid cars, but is produced using a cheaper, less environmentally hazardous process. MIT President Susan Hockfield presents a prototype battery to President Barack Obama at a press briefing at the White House.

2009 Researchers at MIT's Picower Institute for Learning and Memory show for the first time that multiple interacting genetic risk factors may influence the severity of autism symptoms. The finding could lead to therapies and diagnostic tools that target the interacting genes.

2009 Gerbrand Ceder and graduate student Byoungwoo Kang develop a new way to manufacture the material used in lithium ion batteries that allows ultrafast charging and discharging. The new method creates a surface structure that allows lithium ions to move rapidly around the outside of the battery. Batteries built using the new method could take seconds, rather than the now standard hours, to charge.

2009 Li-Huei Tsai's laboratory describes mechanisms that underlie Alzheimer's disease and propose that inhibition of histone deacetylases is therapeutic for degenerative disorders of learning and memory. Her laboratory also discovers the mechanisms of action of the gene Disrupted-in-Schizophrenia 1 and demonstrates why drugs such as lithium are effective in certain instances of schizophrenia. This research opens up pathways to discovering novel classes of drugs for devastating neuropsychiatric conditions.

2010 A new approach to desalination is being developed by researchers at MIT and in Korea that could lead to small, portable desalination units that could be powered by solar cells or batteries and could deliver enough fresh water to supply the needs of a family or small village. As an added bonus, the system would remove many contaminants, viruses, and bacteria at the same time.

2010 Yang Shao-Horn, with some of her students, and visiting professor Hubert Gasteiger, reports that lithium-oxygen (also known as lithium-air) batteries with electrodes with either gold or platinum as a catalyst have a higher efficiency than simple carbon electrodes. Lithium-air batteries are lighter than the conventional lithium-ion batteries.

2010 A team at Media Lab, including Ramesh Raskar, visiting professor Manuel Oliveira, student Vitor Pamplona, and postdoctoral research associate Ankit Mohan, create a new system to determine a prescription for eyeglasses. In its simplest form, the test can be carried out using a small, plastic device clipped onto the front of a cellphone's screen.

2010 MIT releases *The Future of Natural Gas* report. The two-year study, managed by the MIT Energy Initiative, examines the scale of U.S. natural gas reserves and the potential of this fuel to reduce greenhouse-gas emissions. While the report emphasizes the great potential for natural gas as a transitional fuel to help curb greenhouse gases and dependence on oil, it also stresses that it is important as a matter of national policy not to favor any one fuel or energy source in a way that puts others at a disadvantage.

2010 Michael Strano and his team of graduate students and researchers create a set of self-assembling molecules that can turn sunlight into electricity; the molecules can be repeatedly broken down and reassembled quickly just by adding or removing an additional solution.

2010 Lincoln Laboratory developed the Space Surveillance Telescope (SST), an advanced ground-based optical system designed to enable detection and tracking of faint objects in space while providing rapid, wide-area search capability. The SST combines innovative curved charge-coupled device imager technology developed at Lincoln Laboratory with a very wide field-of-view, large-aperture (3.5 meter) telescope. The system is installed at the Atom Site on the White Sands Missile Range in New Mexico being evaluated for detection and tracking of microsatellites before being transitioned to Space Surveillance Network.

2011 Elazer Edelman, graduate student Joseph Franses, and former postdoctoral fellows Aaron Baker and Vipul Chitalia show that cells lining blood vessels secrete molecules that suppress tumor growth and prevent cancer cells from invading other tissues, a finding that could lead to a new cancer treatment.

2011 The Alpha Magnetic Spectrometer (AMS)—an instrument designed to use the unique environment of space to search for antimatter and dark matter and to measure cosmic rays—is delivered to the International Space Station. The AMS experiment, led by Samuel C. C. Ting, is designed to study high-energy particles; such study could lead to new theories about the formation and evolution of the universe.

2011 A team, including Karen Gleason, Vladimir Bulović, and graduate student Miles Barr, develops materials that make it possible to produce photovoltaic cells on paper or fabric, nearly as simply as printing a document. The technique represents a major departure from the systems typically used to create solar cells, which require exposing the substrates to potentially damaging conditions, either in the form of liquids or high temperatures.

2011 By combining a physical interface with computer-vision algorithms, researchers in the Department of Brain and Cognitive Sciences create a simple, portable imaging system that can achieve resolutions previously possible only with large and expensive lab equipment. The device could allow manufacturers to inspect products too large to fit under a microscope and could also have applications in medicine, forensics, and biometrics. Moreover, because the design uses multiple cameras, it can produce 3D models of an object, which can be manipulated on a computer screen for examination from multiple angles.

2011 Researchers, led by Daniel Nocera, have produced an “artificial leaf”—a silicon solar cell with different catalytic materials bonded onto its two sides. The artificial leaf can turn the energy of sunlight directly into a chemical fuel that can be stored and used later as an energy source.

2012 NASA's Gravity Recovery And Interior Laboratory (GRAIL) twin spacecraft successfully enters lunar orbit. By precisely measuring changes in distance between the twin orbiting spacecraft, scientists will construct a detailed gravitational model of the moon that will be used to answer fundamental questions about the moon's evolution and its internal composition. GRAIL's principal investigator is Maria Zuber.

2012 Researchers, including Jeffrey Grossman, discover that building cubes or towers of solar cells—to extend the cells upward in three-dimensional configurations—generates two to 20 times the power produced by fixed flat panels with the same base area.

2012 Researchers, led by Ian Hunter, have engineered a device that delivers a tiny, high-pressure jet of medicine through the skin without the use of a hypodermic needle. The device can be programmed to deliver a range of doses to various depths—an improvement over similar jet-injection systems that are now commercially available.

2012 A clinical trial of an Alzheimer’s disease treatment developed at MIT finds that a nutrient cocktail can improve memory in patients with early Alzheimer’s. Richard Wurtman invented the supplement mixture, known as Souvenaid, which appears to stimulate growth of new synapses.

2012 Researchers, including Young Lee and PhD graduate Tianheng Han, have followed up on earlier theoretical predictions and demonstrated experimentally the existence of a fundamentally new magnetic state called a quantum spin liquid (QSL), adding to the two previously known states of magnetism. The QSL is a solid crystal, but its magnetic state is described as liquid: Unlike the other two kinds of magnetism, the magnetic orientations of the individual particles within it fluctuate constantly, resembling the constant motion of molecules within a true liquid.

2012 Lincoln Laboratory developed a laser communications system to demonstrate high-data-rate communications between a lunar-orbiting NASA satellite and a ground site in the United States. The Lunar Laser Communications Demonstration addresses NASA’s need for very-high-rate, very-long-distance communications systems small enough to fly in space. It transmits over 600 megabits per second using only a 4-inch telescope and a 1/2-watt laser installed on the satellite. The ground receiver is nearly ten times more efficient than any optical receiver ever demonstrated at these high rates.

2013 A new steelmaking process developed by researchers, Donald Sadoway, Antoine Allanore, and former postdoc Lan Yin, produces no emissions other than pure oxygen and carries nice side benefits: The resulting steel should be of higher purity, and eventually, once the process is scaled up, cheaper.

2013 A research team, led by Yuriy Román, has devised a cheaper way to synthesize a key biofuel component, which could make its industrial production much more cost-effective. The compound, known as gamma-valerolactone (GVL), has more energy than ethanol and could be used on its own or as an additive to other fuels. GVL could also be useful as a “green” solvent or a building block for creating renewable polymers from sustainable materials.

2013 A system being developed by Dina Katabi and her graduate student Fadel Adib, could give us the ability to see people through walls using low-cost Wi-Fi technology. The system, called “Wi-Vi,” is based on a concept similar to radar and sonar imaging. But in contrast to radar and sonar, it transmits a low-power Wi-Fi signal and uses its reflections to track moving humans.

2013 Hydrophobic materials—water-shedding surfaces—have a theoretical limit on the time it takes for a water droplet to bounce away from such a surface. Researchers, led by Kripa Varanasi, have found a way to burst through that perceived barrier, reducing the contact time by at least 40 percent. This research could aid ice prevention, wing efficiency, and more.

2014 Lincoln Laboratory develops PANDA (Platform for Architecture-Neutral Dynamic Analysis) enabling software analysts to simplify the analysis and understanding of complex software systems for cyber analysis and threat protection. PANDA allows analysts to quickly develop instrumentation that can help answer complex questions about software and inform appropriate responses. Software developers and analysts can move toward automating tasks that would otherwise be manual, tedious, time-consuming, and costly.

2014 Platinum-group metals can be considered unsustainable resources that are needed catalysts to enable renewable energy technologies. Graduate student Sean Hunt, postdoc Tarit Nimmandwudipong, and Yuriy Román have devised a process of synthesizing renewable alternative catalysts.

2014 Engineers at MIT and Lawrence Livermore National Laboratory (LLNL) have devised a way to translate that airy, yet remarkably strong, structure style of the Eiffel Tower down to the microscale—designing a system that could be fabricated from a variety of materials, such as metals or polymers, and that may set new records for stiffness for a given weight. Nicholas Fang, former postdoc Howon Lee, visiting research fellow Qi “Kevin” Ge, LLNL’s Christopher Spadaccini and Xiaoyu “Rayne” Zheng are among the researchers involved in the project.

2014 Researchers, including Gang Chen and postdoc Hadi Ghasemi, have developed a new material structure—a layer of graphite flakes and an underlying carbon foam—that generates steam by soaking up the sun. The material is able to convert 85 percent of incoming solar energy into steam—a significant improvement over recent approaches to solar-powered steam generation. The setup loses very little heat in the process, and can produce steam at relatively low solar intensity.

2014 Bryan Hsu PhD ’14 and Paula Hammond, working with Myoung-Hwan Park of Shamyook University in South Korea and Samantha Hagerman ’14, have developed a new drug-delivery system method that could enable pain medication and other drugs to be released directly to specific parts of the body. The method uses biodegradable, nanoscale “thin films” laden with drug molecules that are absorbed into the body in steady doses over a period of up to 14 months.

2014 Researchers at MIT, including John Foster, the University of Colorado, including Daniel Baker, and elsewhere have found there’s a hard limit to how close ultrarelativistic electrons can get to the Earth. The team found that no matter where these electrons are circling around the planet’s equator, they can get no further than about 11,000 kilometers from the Earth’s surface—despite their intense energy.

2015 Natalie Artzi and Elazer Edelman, working with other researchers, found that a tissue adhesive they had previously developed worked much differently in cancerous colon tissue than in colon tissue inflamed with colitis. The finding suggests that scientists must take into account the environment in which the material will be used, instead of using a “one-size fits all” approach for this sealant, or any other kind of biomaterial, designed to work inside the human body.

2015 MACHETE, a state-of-the-art airborne lidar system that performs high-resolution, 3D imaging at an area collection rate an order of magnitude higher than other lidar systems, was developed by Lincoln Laboratory. The system is highly optimized for foliage-penetration applications; it can image through dense canopy to reveal structures at and near ground level. The system employs advanced single-photon-counting Geiger-mode avalanche detector array technology, and an ultra-short pulsed laser and gimbaled pointing system to deliver high-altitude, high-resolution 3D imaging.

2015 Kimberly Hamad-Schifferli and Lee Gehrke are among the researchers that have devised a new diagnostic test that is a simple paper strip similar to a pregnancy test, that can rapidly diagnose Ebola, as well as other viral hemorrhagic fevers such as yellow fever and dengue fever. Unlike most existing paper diagnostics, which test for only one disease, the new MIT strips are color-coded so they can be used to distinguish among several diseases.

2015 Research conducted by Polina Anikeeva, graduate student Ritchie Chen, postdoc Gabriela Romero, graduate student Michael Christiansen, and undergraduate Alan Mohr has developed a method to stimulate brain tissue using external magnetic fields and injected magnetic nanoparticles—a technique allowing direct stimulation of neurons, which could be an effective treatment for a variety of neurological diseases, without the need for implants or external connections.

2015 Plants achieve efficient energy transport by making use of the exotic effects of quantum mechanics—effects sometimes known as “quantum weirdness.” These effects, which include the ability of a particle to exist in more than one place at a time, have now been used by engineers to achieve a significant efficiency boost in a light-harvesting system. Researchers at MIT, including Angela Belcher and Seth Lloyd, and Eni, the Italian energy company, use engineered viruses to provide quantum-based enhancement of energy transport to mimic photosynthesis.

2015 MIT engineers have designed what may be the Band-Aid of the future: a sticky, stretchy, gel-like material that can incorporate temperature sensors, LED lights, and other electronics, as well as tiny, drug-delivering reservoirs and channels. The “smart wound dressing” releases medicine in response to changes in skin temperature and can be designed to light up if, say, medicine is running low. The key to the design is a hydrogel matrix designed by Xuanhe Zhao.

2016 A new advance from MIT, Boston Children’s Hospital, and several other institutions may offer a better treatment for Type 1 diabetes, which leaves patients without the ability to naturally control blood sugar by damaging the pancreas. Replacing patients’ destroyed pancreatic islet cells with healthy cells is a treatment with one major drawback—the patients’ immune systems attack the transplanted cells—requiring patients to take immunosuppressant drugs for the rest of their lives. The researchers, including Daniel Anderson, have designed a material that can be used to encapsulate human islet cells before transplanting them without provoking an immune response.

2016 For the first time, scientists have observed ripples in the fabric of spacetime called gravitational waves, arriving at the Earth from a cataclysmic event in the distant universe. This confirms a major prediction of Albert Einstein’s 1915 general theory of relativity. Gravitational waves carry information about their dramatic origins and about the nature of gravity that cannot otherwise be obtained. Physicists have concluded that the detected gravitational waves were produced during the final fraction of a second of the merger of two black holes to produce a single, more massive spinning black hole. This collision of two black holes had been predicted but never observed. The gravitational waves were detected on Sept. 14, 2015 at 5:51 a.m. Eastern Daylight Time (09:51 UTC) by both of the twin Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors, located in Livingston, Louisiana, and Hanford, Washington. The LIGO Observatories are funded by the National Science Foundation, and were conceived, built, and are operated by Caltech and MIT. The discovery was made by the LIGO Scientific Collaboration and the Virgo Collaboration using data from the two LIGO detectors.

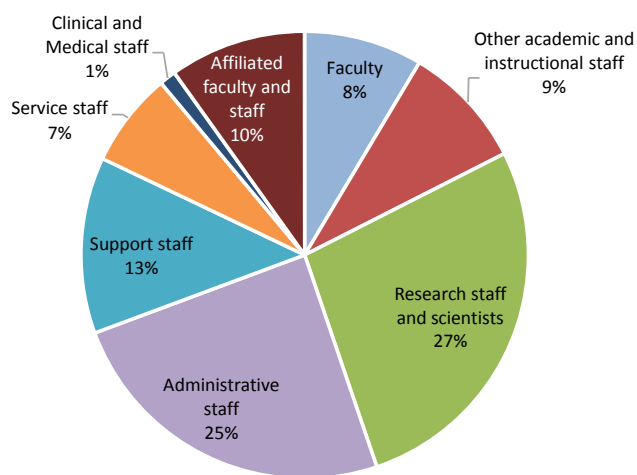
Faculty and Staff

As of October 31, 2015, MIT employs 12,109 persons on campus. In addition to the faculty, there are research, library, and administrative staff, and many others who, directly or indirectly, support the teaching and research goals of the Institute.

Faculty and Staff, 2015–2016

Employee Type	Count
Faculty	1,036
Other academic and instructional staff	1,086
Research staff and research scientists (includes postdoctoral positions)	3,300
Administrative staff	2,974
Support staff	1,543
Service staff	829
Clinical and Medical staff	144
Affiliated faculty, scientists, and scholars	1,197
Total campus faculty and staff	12,109

Faculty and Staff, 2015–2016



Each year, MIT employs about 1,250 graduate students as teaching assistants and 3,600 graduate students as research assistants.

MIT Lincoln Laboratory employs about 3,700 people, primarily at Hanscom Air Force Base in Lexington, Massachusetts. See page 86 for additional Lincoln Laboratory staffing information.

Faculty

The MIT faculty instruct undergraduate and graduate students, and engage in research and service.

Faculty Profile, 2015–2016

	Count	Percent of Total
Professors	665	64
Associate professors	194	19
Assistant professors	177	17
Total	1,036	100
Male	806	78
Female	230	22

See page 48 for a chart of faculty and students from 1865–2016.

Seventy-five percent of faculty are tenured.

Faculty may hold dual appointments where they are appointed equally to two departments. Sixteen faculty members have dual appointments.

Faculty by School, 2015–2016

School	Count	Percentage
Architecture and Planning	84	8
Engineering	378	37
Humanities, Arts, and Social Sciences	174	17
Management	117	11
Science	273	26
Other	10	1
Total	1,036	100

Sixty-three percent of the faculty are in science and engineering fields.

Twenty percent of faculty are members of a U.S. minority group; seven percent of faculty identify with an underrepresented minority group.

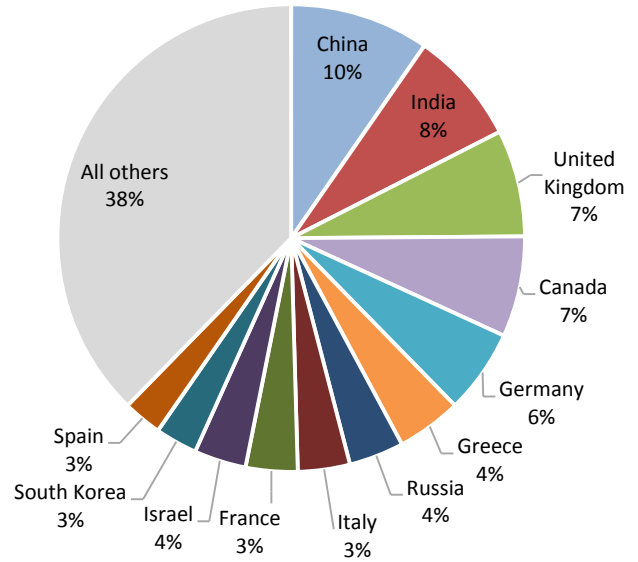
Faculty by U.S. Minority Group, 2015–2016

Ethnicity	Female Count	Male Count
Asian	30	104
Hispanic or Latino	7	34
African American	8	25
American Indian or Alaskan Native	2	1
Native Hawaiian or Other Pacific Islander	1	0

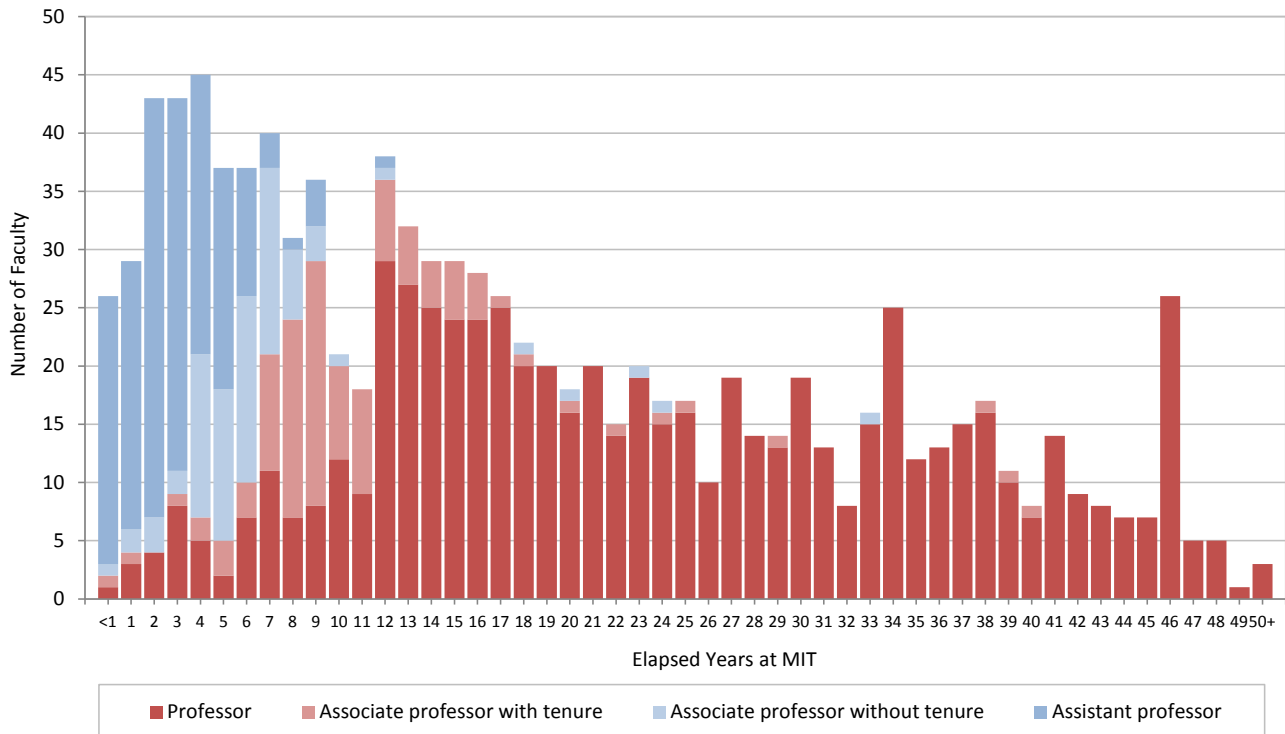
Ethnicity is self-identified, and faculty members may identify with more than one group.

Forty-three percent of current faculty are internationally born. Over seventy countries are represented by these faculty members.

Country of Origin of Internationally Born Faculty, 2015–2016



**Elapsed Years at MIT of Faculty, 2015–2016
(Excludes time as student)**



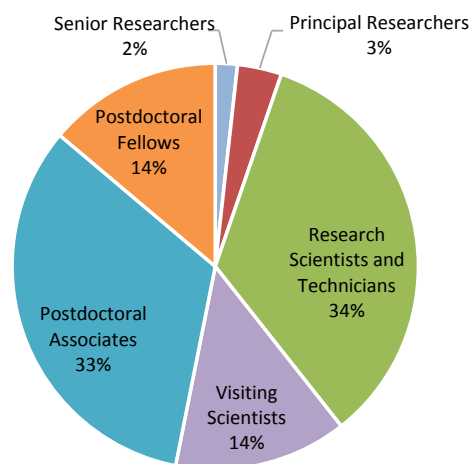
Researchers

MIT campus research staff and scientists total 3,300. These researchers work with MIT faculty and students on projects funded by government, nonprofits and foundations, and industry.

Campus Research Staff and Scientists, 2015–2016

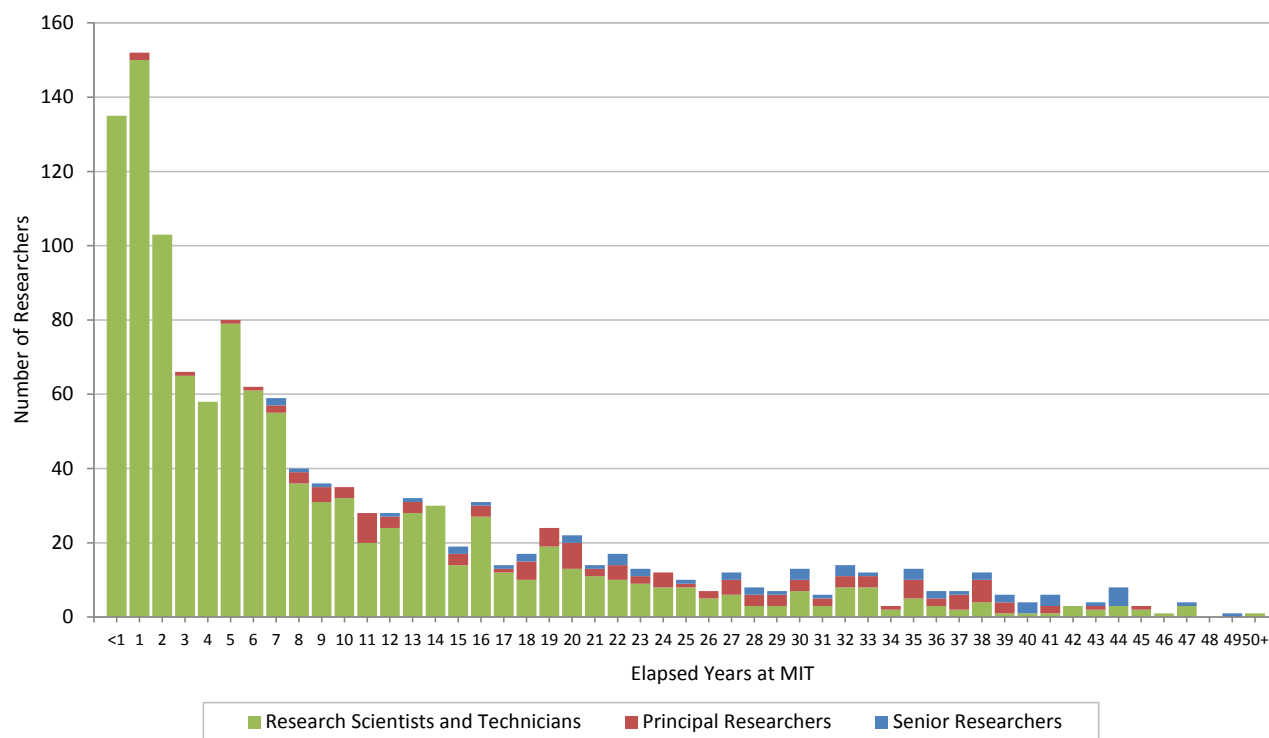
Employee Type	Count
Senior Researchers	58
Principal Researchers	116
Research Scientists and Technicians	1,125
Visiting Scientists	454
Postdoctoral Associates	1,090
Postdoctoral Fellows	457
Total	3,300

Campus Research Staff and Scientists, 2015–2016



In fall 2015, approximately 2,600 graduate students were research assistants.

**Elapsed Years at MIT of Campus Research Staff and Scientists, 2015–2016
(Senior Researchers, Principal Researchers, and Research Scientists and Technicians)**



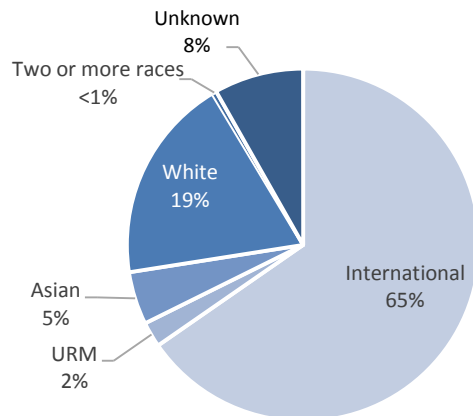
Postdoctoral Scholars

The MIT campus hosts 1,547 postdoctoral associates and fellows—412 females and 1,135 males. These individuals work with faculty in academic departments, laboratories, and centers.

U.S. Citizen and Permanent Resident Postdoctoral Scholars by Ethnicity, 2015–2016

Ethnicity	Count
Hispanic or Latino	29
African American	7
American Indian or Alaskan Native	0
Total underrepresented minorities (URM)	36
White	292
Asian	75
Two or more races	6
Unknown	127
Total	536

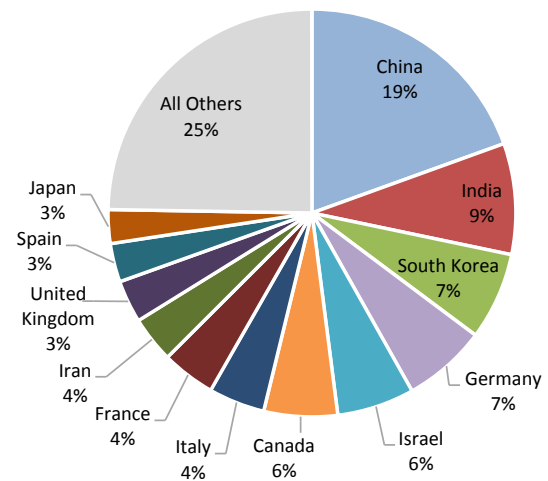
Ethnicity of Postdoctoral Scholars, 2015–2016



International Postdoctoral Scholars Top Countries of Citizenship, 2015–2016

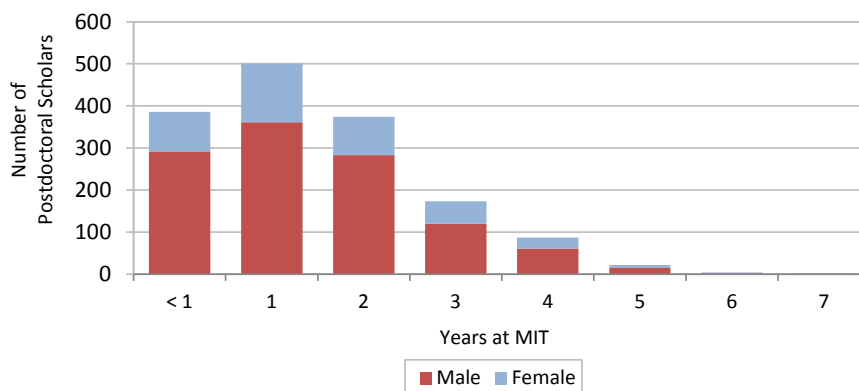
Country of Citizenship	Count
China	197
India	89
South Korea	70
Germany	67
Israel	62
Canada	59
Italy	45
France	43
Iran	37
United Kingdom	34

Country of Citizenship of International Postdoctoral Scholars, 2015–2016



Postdoctoral scholars come from 70 foreign countries.

Years at MIT of Postdoctoral Scholars, 2015–2016



Awards and Honors of Current Faculty and Staff

Nobel Prize

Nine current faculty members at MIT have received the Nobel Prize. They are:

H. Robert Horvitz	Nobel Prize in Physiology or Medicine (shared)
Wolfgang Ketterle	Nobel Prize in Physics (shared)
Robert C. Merton	Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (shared)
Richard R. Schrock	Nobel Prize in Chemistry (shared)
Phillip A. Sharp	Nobel Prize in Physiology or Medicine (shared)
Susan Solomon	Nobel Peace Prize (co-chair of Working Group One recognized under Intergovernmental Panel on Climate Change (IPCC), shared)
Samuel C. C. Ting	Nobel Prize in Physics (shared)
Susumu Tonegawa	Nobel Prize in Physiology or Medicine
Frank Wilczek	Nobel Prize in Physics (shared)

Number of recipients of selected awards and honors current faculty and staff have received

Recipients	Award Name and Agency
151	American Academy of Arts and Sciences Member
98	American Association for the Advancement of Science Fellow
13	American Philosophical Society Member
85	American Physical Society Fellow
21	American Society of Mechanical Engineers Fellow
29	Association for Computing Machinery Fellow
4	John Bates Clark Medal, American Economic Association
3	Dirac Medal, Abdus Salam International Centre for Theoretical Physics
11	Fulbright Scholar, Council for International Exchange of Scholars (CIES)
8	Gairdner Award, Gairdner Foundation
63	Guggenheim Fellow, John Simon Guggenheim Memorial Foundation
17	HHMI Investigator, Howard Hughes Medical Institute (HHMI)
55	Institute of Electrical and Electronics Engineers, Inc. Fellow
1	Japan Prize, Science and Technology Foundation of Japan
3	Kavli Prize, Norwegian Academy of Science and Letters
1	Kyoto Prize, Inamori Foundation of Japan
24	MacArthur Fellow, John D. and Catherine T. MacArthur Foundation
2	Millennium Technology Prize, Millennium Prize Foundation
66	National Academy of Engineering Member, National Academies
31	National Academy of Medicine Member, National Academies
82	National Academy of Sciences Member, National Academies
10	National Medal of Science, National Science & Technology Medals Foundation
1	National Medal of Technology and Innovation, National Science & Technology Medals Foundation
1	Rolf Nevanlinna Prize, International Mathematical Union (IMU)
33	Presidential Early Career Awards for Scientists and Engineers (PECASE)
4	Pulitzer Prize, Pulitzer Board
2	Queen Elizabeth Prize for Engineering, The Queen Elizabeth Prize for Engineering Foundation
4	Royal Academy of Engineering Fellow, Royal Academy of Engineering
5	A. M. Turing Award, Association for Computing Machinery
1	Von Hippel Award, Materials Research Society
2	John von Neumann Medal, Institute of Electrical and Electronics Engineers, Inc.
5	Alan T. Waterman Award, National Science Foundation
3	Wolf Prize, Wolf Foundation

Award Highlights

Four MIT faculty win Presidential Early Career Awards

2016 Presidential Early Career Awards for Scientists and Engineers (PECASE)

President Barack Obama named four MIT faculty among 105 recipients of the 2016 Presidential Early Career Awards for Scientists and Engineers (PECASE), the highest honor bestowed by the U.S. government on science and engineering professionals in the early stages of their independent research careers.

Those from MIT who were honored were:

- Tonio Buonassisi, associate professor in the Department of Mechanical Engineering;
- Cullen Buie, associate professor and the Esther and Harold E. Edergton Career Development Chair in the Department of Mechanical Engineering;
- William Tisdale, assistant professor and the Charles and Hilda Roddey Career Development Professor in the Department of Chemical Engineering; and
- Kay M. Tye, assistant professor and the Whitehead Professorship Chair in the Department of Brain and Cognitive Sciences.

<http://bit.ly/1QiL4bn>

Feng Zhang

2016 Canada Gairdner International Award

Feng Zhang, a core institute member of the Broad Institute, an investigator at the McGovern Institute for Brain Research at MIT, and W. M. Keck Career Development Associate Professor in MIT's Department of Brain and Cognitive Sciences, has been named a recipient of the 2016 Canada Gairdner International Award—Canada's most prestigious scientific prize—for his role in developing the CRISPR-Cas9 gene-editing system.

In January 2013 Zhang and his team were first to report CRISPR-based genome editing in mammalian cells, in what has become the most-cited paper in the CRISPR field. He is one of five scientists the Gairdner Foundation is honoring for work with CRISPR. Zhang shares the award with Rodolphe Barrangou from North Carolina State University; Emmanuelle Charpentier of the Max Planck Institute; Jennifer Doudna of the University of California at Berkeley and Phillippe Horvath from DuPont Nutrition and Health.

<http://bit.ly/1Tna1jO>

Mircea Dincă

2016 National Science Foundation's Alan T. Waterman Award

MIT professor of chemistry Mircea Dincă has been selected as the recipient of the National Science Foundation's 2016 Alan T. Waterman Award. This is the 40th anniversary of this prestigious prize, which is the foundation's highest honor recognizing an outstanding researcher under the age of 35.

"It's a pleasure to recognize Dr. Dincă as this year's recipient of the Alan T. Waterman Award," said National Science Foundation (NSF) Director France Córdoba. "His research in microporous solids is revolutionizing how scientists approach this exciting new technology, opening the door for future discoveries."

<http://bit.ly/23Z3xN2>

Section 2

Major MIT Initiatives

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National Policy Initiatives

MIT has had major involvement in technology policy at the national level since before World War II, with MIT faculty and administrators frequently serving as advisors to national policymakers. A more formal “policy initiative” model first emerged in 2005, when incoming MIT President Susan Hockfield announced that MIT would create a major cross-disciplinary, cross-school initiative around energy. Over the intervening decade, policy initiatives have been created to tackle several other science and technology issues with national, and often global, policy dimensions. Inherently cross-disciplinary, these initiatives draw on deep MIT expertise across science and engineering disciplines, the social sciences, economics, and management. Major policy initiatives to date are described below. Some have had relatively short-term, specifically defined goals, while others, such as the original energy initiative, address broader long-term goals and are ongoing.

Energy

The MIT Energy Initiative (MITEI) was formally launched in the fall of 2006, following the recommendations of the 2006 Report of the Energy Research Council regarding new approaches to multidisciplinary research, education across school and department boundaries, energy use on campus, and outreach to the policy world through technically grounded analysis.

MITEI is now recognized as the first and the foremost campus-wide energy program at a U.S. academic institution, with important educational, research, and policy components. MITEI’s educational activities affect MIT students at every level, from incoming freshmen who learn about energy issues in pre-orientation to the Energy Studies Minor, through undergraduates who use MITEI-developed curricular materials in many classes and can now obtain an Energy Studies Minor, to graduate fellows researching national and international energy issues. MITEI has helped energy research at MIT grow by developing strategic alliances with companies across a broad range of energy-related businesses, attracting government and philanthropic support, and stimulating faculty members from across the campus to consider how their research expertise is relevant to energy issues. Its policy outreach component

has similarly prospered, encompassing core MITEI activities and those under the auspices of programs such as the Center for Energy and Environmental Policy Research (CEEPR) and the Joint Program on the Science & Policy of Global Change. MITEI, CEEPR, and the Joint Program each hold workshops at least annually to bring MIT faculty, research staff, and students together with outside experts to address current technological, economic, and political challenges in energy and climate.

MITEI’s best-known policy products are the eleven in-depth, multidisciplinary “Future of ...” studies released to date (see <http://mitei.mit.edu/publications/reports-studies/future>).

New “Future of” studies will continue to inform future decisions regarding energy research, technology choices, and policy development. *The Utility of the Future: Preparing for a Changing Energy Sector* is expected to be released in the fall of 2016, and additional studies are in the planning stages.

As it enters its second decade, MITEI is organizing its research efforts around specific technology research areas, with associated Low-Carbon Energy Centers supporting sustained collaboration across academia, industry, government, and the philanthropic and NGO communities. The first five Low-Carbon Energy Centers will bring together stakeholders in Solar; Storage; Materials for Energy and Extreme Environments; Carbon Capture, Utilization, and Storage; and Advanced Nuclear Systems. (See <https://mitei.mit.edu/research/low-carbon-energy-centers>.)

Convergence

“Convergence” is a term for the merging of distinct technologies, integrating disciplines, into a unified whole that creates a host of new pathways and opportunities. It involves the coming together of different fields of study—particularly engineering, physical sciences, and life sciences—through collaboration among research groups and the integration of approaches that were originally viewed as distinct and potentially contradictory. Convergence implies a broad rethinking of how all scientific research can be conducted, to capitalize on a range of knowledge bases, from microbiology to computer science to engineering design. It is a new organizational model

for innovation, taking the tools and approaches of one field of study and applying them to another, paving the way for advances in all fields involved. At MIT the policy focus has been on Convergences for biomedical advances.

In 2011, then-President Susan Hockfield appointed Institute Professors Phillip Sharp and Robert Langer to lead a faculty committee which developed a widely cited whitepaper entitled *Third Revolution: Convergence of The Life Sciences, Physical Sciences And Engineering*. Simultaneously, MIT created the Koch Institute for Integrative Cancer Research and organized it around the convergence research model, with biologists, engineers and physical scientists working in close collaboration.

Support for this integrated research approach continues to grow. MIT continues to be a leader in the Convergence revolution on campus and beyond. At MIT, this model is now deeply anchored in many areas of life sciences, including work in quantum information studies of neurons, neuroscience and computing, synthetic biology, and cancer research. Just as engineering and physical sciences are transforming the life sciences, biological models are transforming engineering and physical science, with campus research in biofuels, biomaterials, and viral self-assembly drawing on the Convergence model.

The White House featured “Fostering Convergent Science” in its January 2013 Blueprint For Action, and included advancing the convergence approach among four annual goals. Later that year, President Obama announced the BRAIN (Brain Research through Advancing Innovative Neurotechnologies) initiative, a major public-private partnership utilizing a convergence research approach, with federal participation by NIH, NSF, and DARPA complemented by contributions from companies, health systems, patient advocacy organizations, philanthropists, state governments, research universities, private research institutes, and scientific societies. In 2015, the White House launched the Precision Medicine initiative across three agencies, aimed at applying big data and analytics to enable personalized medicine approaches. In 2016, the White House launched a new Microbiome initiative, also organized on a convergence research model.

The National Academies of Science has also provided leadership in the convergence effort through its Board on Life Sciences. The Board’s September 2013 workshop on “Key Challenges in the Implementation of Convergence,” was co-chaired by MIT President Emerita Hockfield. The workshop findings are summarized in *Convergence—Facilitating Transdisciplinary Integration of Life Sciences, Physical Science, Engineering and Beyond* (National Academies Press, 2014).

At the American Association for the Advancement of Science’s 2014 Annual Meeting, Professor Phillip Sharp delivered the AAAS President’s Lecture on the topic of Convergence; President Emerita Hockfield led a AAAS workshop on the topic.

The Defense Advanced Research Projects Agency (DARPA) has been expanding its focus on convergence model research, forming a new Biological Technologies Office in 2014 with a research portfolio in areas including bio-fabrication, neuroscience, and infectious disease, and leading DARPA’s participation in the BRAIN initiative.

In the past year, MIT has twice convened large groups of experts from around the country to discuss the role of Convergence research in the future of health and healthcare, aiming to develop the framework for a research strategy for biomedical convergence. Cross-sector workshops were held in December 2015 at the American Academy of Arts and Sciences and in March 2016 at the American Association for the Advancement of Science, with contributing experts from academia, industry, government, and philanthropy. A policy report drawing on these convenings is scheduled for release in June 2016.

Additional information on the convergence research model, including further details on major developments described above, is available online at <http://www.convergencerevolution.net/>.

Advanced Manufacturing

MIT leaders have played a major role in the design of national efforts to confront structural problems in the U.S. manufacturing sector, starting in 2011 with the MIT Production in the Innovation Economy (PIE) study project. Building on PIE research, national policy work continued with MIT taking a leadership role in the President's Advanced Manufacturing Partnership (AMP). Two major reports (AMP1.0, 2012, and AMP2.0, 2014) were issued, and led to federal support for a network of regional institutes to promote manufacturing innovation, which became the Administration's largest new technology initiative and focus. These competitively selected partnerships between federal research agencies and state governments, academia, and private companies seek to integrate new technologies and processes into the U.S. manufacturing industry and ensure that workers have the knowledge and skills needed to implement these innovations domestically. On campus, this focus on advanced manufacturing has led to new research and educational activities while stimulating regional outreach to and partnerships with manufacturers and other educational institutions. It has also helped define the campus-wide innovation initiative.

Campus leaders in manufacturing, including President L. Rafael Reif, Provost Martin A. Schmidt, and Professor Krystyn J. Van Vliet, who were the Technical co-leads of AMP, continue to engage with key federal officials and business leaders to help pave a robust path for the utilization of advanced technologies by U.S. manufacturers. Further details follow below.

Production in the Innovation Economy Study

This MIT study (known as PIE) issued its final report in two volumes from MIT Press (released in September 2013 and January 2014). The report identified a major decline in the ecosystem of support for small and mid-sized production firms and gaps in financing for production scale-up and in workforce training, drawing lessons from production practices abroad, particularly Germany and China. The report recommended a new innovation effort around what it termed "advanced manufacturing," to be shared across industry and universities, with new financing, workforce training and collaborative R&D efforts. The PIE report was presented at a major campus forum on September 20-21, 2014, led by MIT President Reif,

including Dow Chemical CEO Andrew Liveris, who co-led the Advanced Manufacturing Partnership, and senior federal officials. The National Academy of Sciences hosted key PIE researchers at a November 1 presentation of the PIE report, in its historic Lecture Room in Washington, led by PIE Commission co-chair Suzanne Berger. They summarized the study results to a packed house of federal officials and representatives from industry, universities, and non-governmental organizations. Professor Berger subsequently testified about the PIE findings before the Senate Banking and Senate Commerce Committees, and briefed forums at think tanks and foundations, as well as the President. President Obama's Administration drew extensively on expertise from the PIE study. The key PIE research findings were discussed on an ongoing basis as the report was developed with industry and government, including directly with President Obama and his senior officials, and had a major effect on developing national manufacturing policies, through the AMP process discussed below. In effect, the MIT initiative flowed almost seamlessly into national manufacturing policy creation at the highest levels.

Advanced Manufacturing Partnership

MIT Presidents Susan Hockfield and Rafael Reif were named by President Obama as successive co-chairs of the steering committee for his industry-university Advanced Manufacturing Partnership (AMP) in its two phases, from 2012 through 2014. MIT Provost Martin Schmidt and Professor Krystyn Van Vliet served as successive technical co-leads for AMP1.0 and AMP2.0.

The AMP1.0 report in 2012 proposed the establishment of a new network of advanced manufacturing institutes, modeled on the German Fraunhofer institutes. The AMP2.0 report, released in October 2014, refined the recommendations for what is now known as the National Network for Manufacturing Innovation (NNMI). It also proposed strategies for collaborative R&D efforts across leading federal agencies, best practices for apprenticeship and training programs, and policies to support financing of production scale-up for advanced manufacturing processes and technologies. President Reif and Provost Schmidt led the AMP2.0 Steering Committee, along with DOW CEO Andrew Liveris, and the President's National Economic Council Director, Science Advisor, and Commerce Secretary, in

2013–2014. Professor Van Vliet co-chaired the AMP2.0 technology development workgroup, which prepared model technology strategies on digital manufacturing, advanced materials for manufacturing, and sensors/measurement/process control areas. She continues to help set the path for the NNMI as a member of the Leadership Council for the MFOresight advisory group (see www.mforesight.org).

Manufacturing Innovation Institutes

Fifteen Manufacturing Innovation Institutes (MIIs) will be stood up by the end of 2016, with lead sponsorship from the Departments of Commerce, Energy, and Defense. Combined federal, state, and industry funding for these institutes is expected to exceed a half billion dollars annually.

MIT participates in several of the eight institutes operating as of May 2016, and has leadership roles in two. MIT faculty members Michael Watts and Lionel Kimerling lead the technology development and workforce education teams, respectively, for the AIM Photonics Institute. AIM Photonics, a regional consortia including New York and Massachusetts firms and universities, was established by the Department of Defense in July 2015 to develop integrated photonic devices. In April 2016, Secretary of Defense Ash Carter visited the MIT campus to announce that DOD's newest manufacturing institute, would be the Advanced Functional Fabrics of America. AFFOA is establishing headquarters in Cambridge, Massachusetts. Professor Yoel Fink directs the institute, which is managed by an independent nonprofit organization founded by MIT. Regional and national partners are participating in the institute, which will integrate revolutionary fibers into textiles to make new capabilities available to U.S. clothing and soft goods manufacturers.

The “Future Postponed”—addressing the Innovation Deficit

Federal support is the primary mainstay of U.S. science research. As federal R&D funding has stagnated, new ways of explaining to policy makers the central societal need for science is required. The MIT report *The Future Postponed: Why Declining Investment in Basic Research Threatens a U.S. Innovation Deficit*, released in April 2015, was a new way of explaining science and is designed to be accessible to policymakers. The

Future Postponed explains the critical importance of federal investment in science research to grow the economy, develop better therapies and cures, stay competitive, and solve global challenges.

The MIT Committee to Evaluate the Innovation Deficit, named in October 2014 comprised of 30 MIT faculty and researchers from across all schools at MIT, selected and wrote case studies of 15 vital areas of science and engineering from infectious disease, to batteries, Alzheimer's, cybersecurity, catalysis, economics and plant science. The report is not a list of priorities in science research, but rather a short set of illustrative examples from a much longer list of critical fields worthy of investment.

The science community has tried to tell the stories of how past investments in research have paid off in today's technologies—like GPS, MRI, and the Google search engine—but has not adequately told how research cutbacks today will affect the science of tomorrow. The “Future Postponed” report explores the remarkable technology opportunities that lie ahead and the science needed to get there, all fully vetted by a faculty review board, but written in short two or three page case studies that are highly accessible to non-scientist readers. It's a vision of the future of innovation in America and a call for sustained support for research.

The report gained national press attention in such forums as the Wall Street Journal, the New York Times, Reuters, the Los Angeles Times, and others. A group from the faculty committee, led by Professor Marc Kastner, former MIT Dean of Science, held a forum hosted by the AAAS and briefed Congressional staff, White House staff, and other national stakeholders during a Washington DC visit on April 27th.

A second national phase of the report is now wrapping up, with Professor Kastner leading an advisory committee of noted scientists from outside MIT to develop a dozen additional case studies. The 2015 report is available at <http://dc.mit.edu/innovation-deficit>. Additional case studies are posted online at www.futurepostponed.org, and will be collected in a new report expected in the fall of 2016.

Innovation

In October 2013, President Reif announced an “innovation initiative” at MIT, which was followed by a report on the proposed project in December 2014, http://innovation.mit.edu/sites/default/files/images/MIT_Innovation_Initiative_PreliminaryReport_12-03-14.pdf. The initiative has primarily focused on MIT itself. As summarized on its website (<http://innovation.mit.edu/about>) the report emphasizes:

- **Capability-building Programs:** Growing existing education opportunities while creating a select few new programs of interest to MIT students and faculty
- **Convening Infrastructure:** Expanding maker and collaborative spaces across campus and creating digital tools that connect them into a unified campus
- **Communities:** Linking the MIT community more deeply with corporations, governments, and innovation hubs in Cambridge and around the world
- **Lab for Innovation Science and Policy:** an organized effort to develop the ‘science of innovation’ and evidence-base to inform both internal and external program design

In May 2015, President Rafael Reif announced a new innovation programmatic focus in a Washington Post op ed (<http://newsoffice.mit.edu/2015/reif-op-ed-washington-post-0524>). President Reif emphasized the need for regional and national policy elements to fill a gap he identified in the national innovation system. He noted that startups in non-IT fields face major challenges in scaling up to a point where their technologies are demonstrated, tested and de-risked, and placed in range of follow-on financing mechanisms. Calling for new innovation “orchards,” a team at MIT is now exploring relevant models nationwide, and considering new innovation institutions to fill this gap that could be implemented by MIT and regional partners in Massachusetts.

Online Education

MIT’s pioneering support for online education has been in the national spotlight since the announcement by President Charles Vest, in 2001, that the institute would make materials from all its courses freely available through OpenCourseWare (OCW). Now part of the Office of Digital Learning (ODL), OCW has delivered lecture notes, exams, and videos from over 2000 MIT courses to 200 million learners and educators. In May 2012, building off the success of OCW and extending a tradition of educational innovation as old as the institute itself, MIT joined together with Harvard University to create edX. Massively Open Online Courses are available via the edX platform to anyone with Internet access. In the first three years of operation, over five million learners have participated in edX courses online. Over half a million learners have received certificates of completion for courses offered by MIT and edX partner institutions, including nearly 100 courses to date developed and produced by ODL under the MITx nameplate. edX has also begun to offer coordinated collections of courses, called XSeries, which allow for rich exploration of a subject.

The policy aspects of MIT’s digital learning initiative came into focus with President Rafael Reif’s announcement, in April 2013, of an Institute-wide *Task Force on the Future of MIT Education*. He charged the taskforce with capturing an integrated understanding of how online access is changing teaching and learning. The task force looked at impacts on our own campus and beyond, and began to envision how future technologies and models can spark innovation in higher education. The task force’s work culminated with the release of a final report available at <http://bit.ly/1JSkNJM>.

In August 2014, Professor Sanjay Sarma and Professor Karen Wilcox, who had co-chaired the *Task Force on the Future of MIT Education*, assumed the leadership of a study of the national policy aspects and implications of online education, with support from the Carnegie Foundation. This Online Education Policy Initiative (OEPI) explored teaching pedagogy and efficacy, institutional business models, and global educational engagement strategies. The Online Education Policy Initiative released its final report, *Online Education: A Catalyst for Higher Education Reform* on April 1st,

2016 at the National Academy of Sciences (see <https://oepe.mit.edu/final-report>). The report was also briefed to Congressional committees, NSF, the White House, and higher education groups. The report synthesizes numerous discussions among the initiative's internal (MIT) advisory committee, as well as with an external advisory committee representing associations and companies involved in higher education and other universities. Important input to the OEPI was also obtained through a May 2015 workshop, sponsored by the National Science Foundation, which brought fifty practitioners from the learning science and online learning technology communities together to discuss emerging ideas about online pedagogy.

Online Education: A Catalyst for Higher Education Reform makes four principal recommendations.

1. To deepen integration of research across all the fields that impact learning, the community should develop an integrated research agenda emphasizing interdisciplinary collaborations.
2. Digital technologies can provide a dynamic scaffolding to facilitate effective learning. They should be promoted to facilitate customized learning, remote collaboration, and continuous assessment, and to support teachers while allowing them to focus on high-value in-person interactions with students.
3. A new class of creative, professional educators, which the report calls "learning engineers," should be encouraged and supported. Learning engineers would integrate deep disciplinary knowledge with broad understanding of the learning and cognitive sciences, educational technology, and online tools.
4. Institutional and organizational change is needed to implement these reforms. Stakeholders across the higher education community can foster change by creating thinking communities and identifying change agents and role models.

Policymakers and leaders in education are already using the report to deepen the public discourse surrounding online learning and to encourage productive discussion about the future of higher education in the U.S. and globally.

Research Initiatives

Cybersecurity Initiatives

In 2015, MIT launched three campus-wide cybersecurity efforts aimed at addressing the technical, regulatory and managerial aspects of cybersecurity. The three initiatives: MIT Cybersecurity Policy Initiative, Cybersecurity@CSAIL, and MIT Sloan's Interdisciplinary Consortium for Improving Critical Infrastructure Cybersecurity (IC)³, are intended to provide a cohesive, cross-disciplinary strategy to tackling the complex problems involved in keeping digital information safe.

MIT Cybersecurity Policy Initiative

MIT Cybersecurity Policy Initiative's goal is to create a new field that will help governments and other responsible institutions create public policy frameworks that will increase the trustworthiness of the interconnected digital systems that will be the foundation of the future flourishing of our societies and on which we are already inexorably dependent. This campus wide initiative, housed in CSAIL, has already produced important research results contributing to current debates on the security of new electronic surveillance proposals. Working with colleagues from around the world, the initiative produced a paper, that has been widely cited at several legislative hearings in the U.S. Senate and reported in the world press. This paper analyzes security risks of new wiretapping proposals propounded by law enforcement agencies in the United States and the United Kingdom. Additionally, as part of the Initiative's mission to train a new generation of technology policy leaders, in the spring of 2015, Initiative leaders ran an experimental course jointly with Georgetown Law School on privacy technology and legislation. The course gave students a high intensity introduction to privacy law and associated computer systems design questions. In 2015–16, initiative faculty are planning to organize a series of workshops on topics such as critical infrastructure security threats, cyberwar norms, global electronic surveillance technical and human rights risks, and cyber insurance markets.

Cybersecurity@CSAIL

Cybersecurity@CSAIL launched in 2015 with 5 founding industrial partners, the goal of CyberSecurity@CSAIL is to identify and develop technologies to address the most significant security issues confronting organizations in the next decade. Presently, approaches to system security do not give overall security guarantees, but rather attacks are fought individually—“patch and pray” style. CyberSecurity@CSAIL aims to provide an integrated and formal approach to the security of systems, combining design and analysis methods from cryptography, software and hardware. Cybersecurity@CSAIL’s approach includes three key elements: collaborate closely with industry for input to shape real-world applications and drive impact; approach the problem from a multi-disciplinary perspective; and create a test-bed for our industry partners to implement and test our tools as well as have our researchers test tools developed by our partners.

MIT Sloan’s Interdisciplinary Consortium for Improving Critical Infrastructure Cybersecurity (IC)³

MIT Sloan’s Interdisciplinary Consortium for Improving Critical Infrastructure Cybersecurity (IC)³ addresses the important strategic, managerial and operational issues related to cybersecurity of the nation’s critical infrastructure, ranging from energy and healthcare to financial services. An MIT cross disciplinary team lead by Sloan, along with industry partners (such as: ExxonMobil, Schneider Electric, State Street Bank), looks to address issues, such as cyber risk analysis, return on cybersecurity investment, application of cybersafety models, incentives for more effective information sharing, establishing a better organizational cybersecurity culture, methods for disrupting the cybercrime ecosystem, and metrics and models to better protect organizations.

<http://ic3.mit.edu>

Environmental Solutions Initiative

The Environmental Solutions Initiative (ESI) is designed to leverage the traditionally open atmosphere at MIT, which fosters interactions among people working in very different fields of study. That spirit of collaboration, and the possibilities it unleashes, are very powerful. ESI is designed to advance new interdisciplinary approaches spanning natural and social sciences, engineering, management, policy, and the humanities to help drive the kind of progress required in time to make a difference.

MIT is already a powerhouse of environmentally oriented research, education, and innovation. ESI is building on this vibrant foundation using seed grants to encourage new, cross-disciplinary research partnerships that advance progress and solutions on issues of environmental significance to humanity. A total of 59 teams of faculty, research staff and students responded to the first call for proposals, from which nine winners were announced on March 13, 2015. Projects launched in September 2015.

Education—both curricular and experiential—is integral to ESI’s mission. Understanding the complexity of human and natural systems and the essential relationship between environmental quality and human welfare is increasingly important for professionals and scholars in a diverse array of fields. ESI’s educational role is to provide integrative, multi-disciplinary opportunities for MIT students to develop their capacity as leaders in environment and sustainability. ESI’s Education Committee, composed of faculty, staff and students, is already at work advancing this agenda. A five-year grant from the Dirk (’75) and Charlene (’79) Kabcenell Foundation is supporting the development of a new Institute Minor in Environment and Sustainability.

<http://environmentalsolutions.mit.edu/>

Abdul Latif Jameel World Water and Food Security Lab

The new Abdul Latif Jameel World Water and Food Security Lab (J-WAFS) serves to organize and promote food and water research around campus, emphasizing innovation and deployment of effective technologies, programs, and policies in order to have measurable impact as humankind adapts to a rapidly changing planet and combats water and food-supply scarcity. The lab addresses the collective pressures of population growth, urbanization, development, and climate change—factors that endanger food and water systems in developing and developed countries alike. To accomplish this, the lab develops broad-based approaches employing MIT's interdisciplinary strengths and expertise in science, engineering and technology, climate and hydrology, energy and urban design, business, social science, and policy. J-WAFS, as an interdepartmental lab reporting to the Vice President for Research, spearheads the efforts of MIT's faculty, labs, and centers to work towards solutions for water and food security that are environmentally benign and energy-efficient, including the development of transformative water and food technologies. These efforts are supported in part through seed grants distributed competitively to MIT researchers from J-WAFS' endowment, established in 2014 through a generous gift by alumnus Mohammed Abdul Latif Jameel '78.

J-WAFS also seeks to partner with other institutions, foundations, industry, philanthropists, and governments to develop regionally appropriate solutions and innovations, whether for fast-growing megacities or for the rural developing world. Water supply in urban settings, for example, may benefit from conservation policies and infrastructure-scale systems, whereas rural populations may need small-scale, locally powered water purifiers. Ensuring stable food supplies requires a similarly varied approach that engages technology, biological and environment science, policy, and business innovation. J-WAFS also supports graduate student-driven food and water research and business communities on campus, through fellowships, conference sponsorship, and other mentoring and assistance.

<http://web.mit.edu/jwafs/>

MIT Energy Initiative

The MIT Energy Initiative (MITEI) plays an important catalytic role in accelerating responses to the many challenges facing our global energy system. MITEI supports energy research teams across the Institute by bringing them together with government and industry to analyze challenges and develop solutions. MITEI also leads Institute energy education efforts and delivers comprehensive analyses for policy makers. Its accomplishments are enabled through the investment of member companies, government sponsors, and donors. From these funding sources, MITEI has raised more than \$585 million to date to support MIT and MITEI Research, Education, and Outreach programs.

MITEI is an Institute-wide initiative that, in its depth and breadth, is without peer at U.S. academic institutions. MITEI-sponsored researchers are developing cutting-edge solutions and bringing new technologies to the marketplace. MITEI 2015 accomplishments include the acquisition of eight new members, the launch of two new consortia, and the release of *The Future of Solar Energy*, the newest in the series of "The Future of..." studies.

MITEI members have sponsored more than 800 projects, many involving collaborations between MIT researchers and member researchers. Nearly 30 percent of the MIT faculty is engaged with MITEI's programs.

The MITEI Seed Fund Program supports innovative early-stage research projects that address energy and related environmental issues. Including 2015 grants, the MITEI Seed Fund Program has supported a total of 140 energy-focused research projects representing nearly \$17.4 million in funding over the past eight years. The program encourages researchers from throughout MIT's five schools to collaborate in exploring new energy-related ideas, and attracts a mix of established energy faculty as well as many who are new to the field or to MIT.

More than two-thirds of MITEI's research portfolio reflects its core mission of enabling the low-carbon economy of the future through the adoption of renewable energy, energy efficiency, and carbon management technologies. The largest single area of funded research is solar energy technology and policy. Much of the remainder of the portfolio is concerned with meeting contemporary energy needs through the efficient use of conventional energy sources.

This year, MITEI funded nine undergraduate energy curriculum projects through a grant from the S.D. Bechtel, Jr. Foundation. It has awarded nearly 350 graduate fellowships in energy and supported well over 200 Undergraduate Research Opportunities Program (UROP) students since 2008. In 2015, with the graduation of 19 Energy Studies Minor students, the Minor achieved a milestone: 108 students have graduated since the Minor began in 2009. Faculty associated with MITEI help shape energy education at both the undergraduate and graduate levels, by teaching, advising, and developing new curricula.

MITEI's outreach program promotes and disseminates energy research findings to the MIT community, as well as to policy makers, industry leaders, and other stakeholders. Through colloquia, symposia, and seminars, MITEI introduces energy thought leaders from across the energy value chain to the local audience, which includes the MIT community, students and faculty at nearby colleges and universities, as well as Boston and Cambridge area politicians, energy industry personnel, and interested residents.

<http://mitei.mit.edu/>

Section 3

Students

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Students

The Institute's fall 2015 student body of 11,331 is highly diverse. Students come from all 50 states, the District of Columbia, three territories and dependencies, and 120 foreign countries. The Institute's 3,411 international students make up eleven percent of the undergraduate population and 43 percent of the graduate population. See pages 110-111 for more information about international students.

Student Profile, 2015–2016

Student Level	Count	Percentage
Undergraduate	4,527	40
Graduate	6,804	60
Total	11,331	100

In fall 2015, 46 percent of MIT's first-year students (who reported their class standing) were first in their high school class; 93 percent ranked in the top five percent.

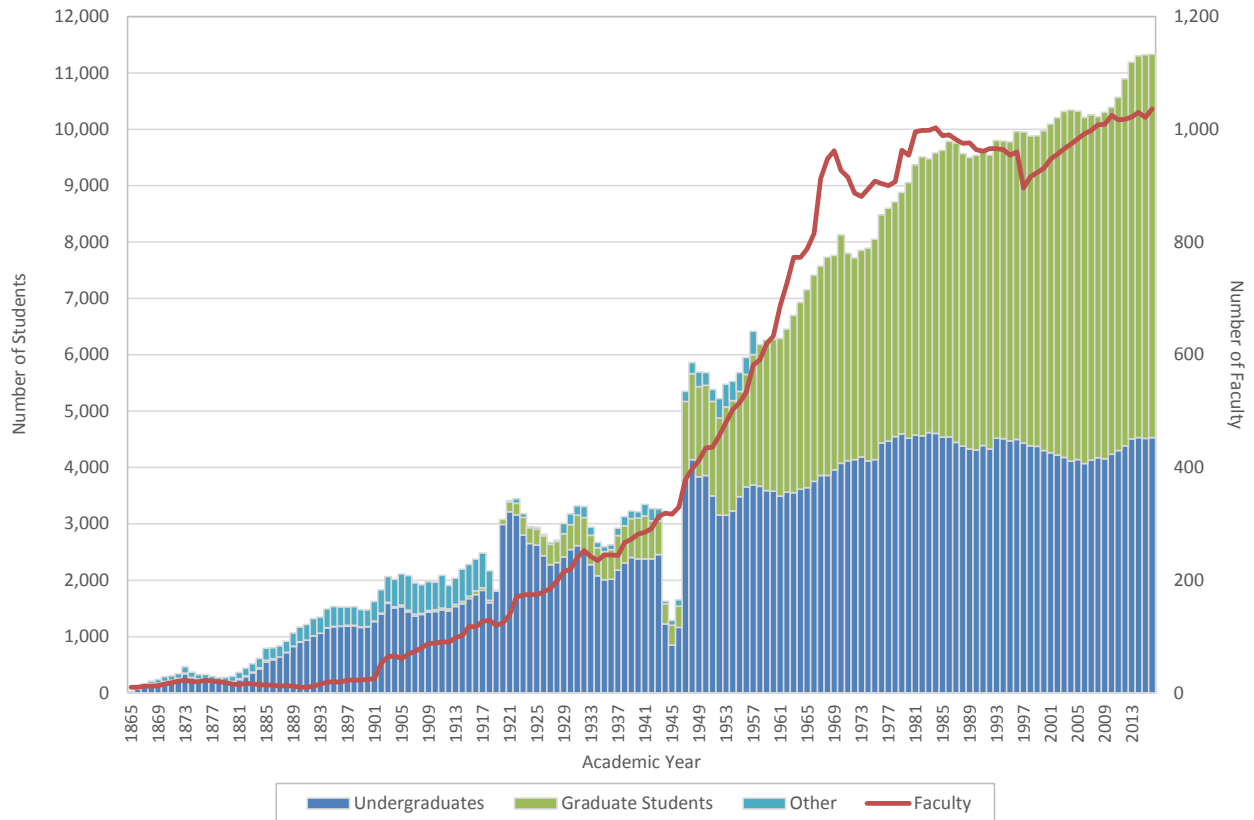
U.S. Citizen and Permanent Resident Student Minorities, 2015–2016

Ethnicity	Undergraduate Count	Graduate Count
Asian American	1,259	840
Hispanic or Latino	682	385
African American	337	118
American Indian or Alaskan Native	46	40
Native Hawaiian or Pacific Islander	8	7

Students may identify with more than one race or choose not to identify with a group. Seventy-nine undergraduates and 427 graduate students chose not to identify an ethnicity or race. These figures may not precisely reflect the population because they are self-reported.

Students who identified, at least in part, as a U.S. minority group totaled 3,709—51% of undergraduate and 20% of graduate students.

Faculty and Students, 1865–2016



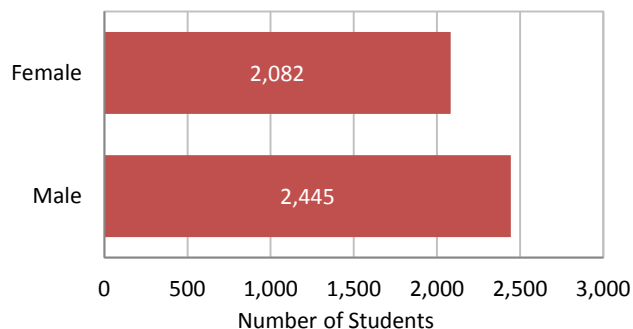
Undergraduate Students

Students first enrolled at MIT in 1865. Twenty-seven students enrolled as undergraduate students that first year. In fall 2015, there were 4,527 undergraduate students.

Undergraduate Students by Citizenship, 2015–2016

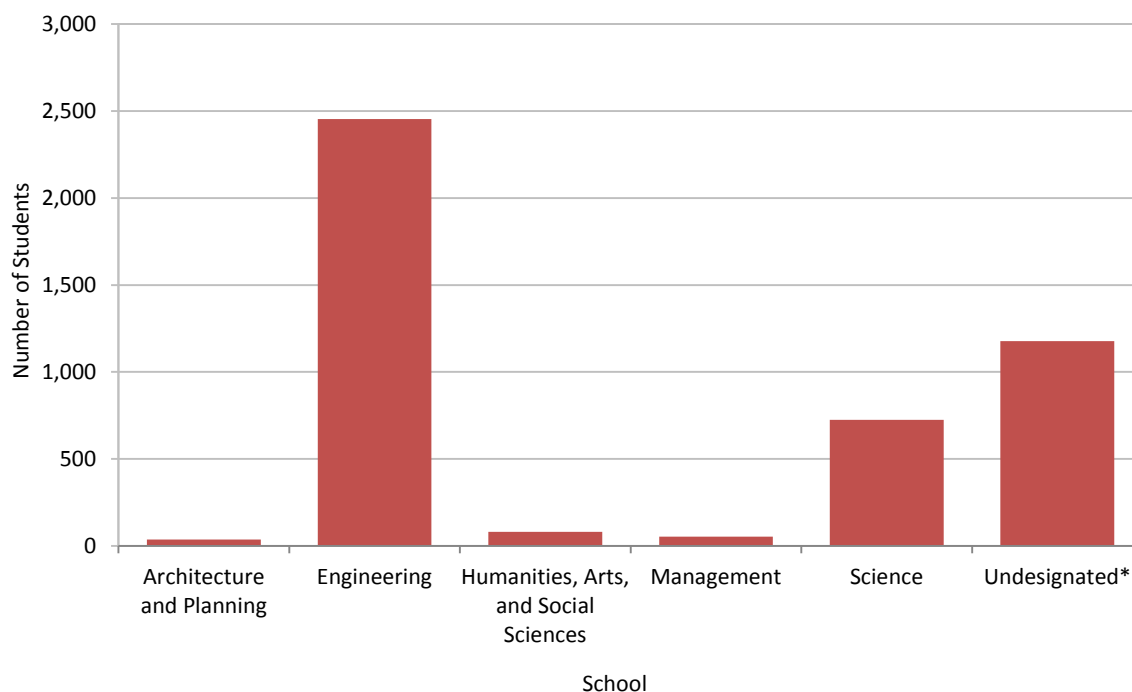
Citizenship	Count	Percentage
U.S. citizen	3,836	84.7
U.S. permanent resident	206	4.6
International	485	10.7
Total	4,527	100.0

Undergraduate Students by Gender, 2015–2016



Undergraduate Students by School, 2015–2016

School	Count
Architecture and Planning	37
Engineering	2,455
Humanities, Arts, and Social Sciences	81
Management	52
Science	724
Undesignated*	1,178
Total	4,527



*Undesignated comprises freshman who do not enroll in a major and undesignated sophomores.

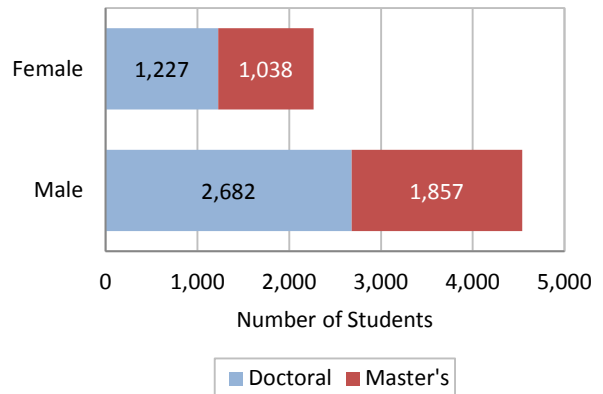
Graduate Students

Graduate students have outnumbered undergraduate students at MIT since 1980. In fall 2015, they comprised 60 percent of the student population with 6,804 students—2,895 master’s students (includes 173 non-matriculating) and 3,909 doctoral students.

Graduate Students by Citizenship, 2015–2016

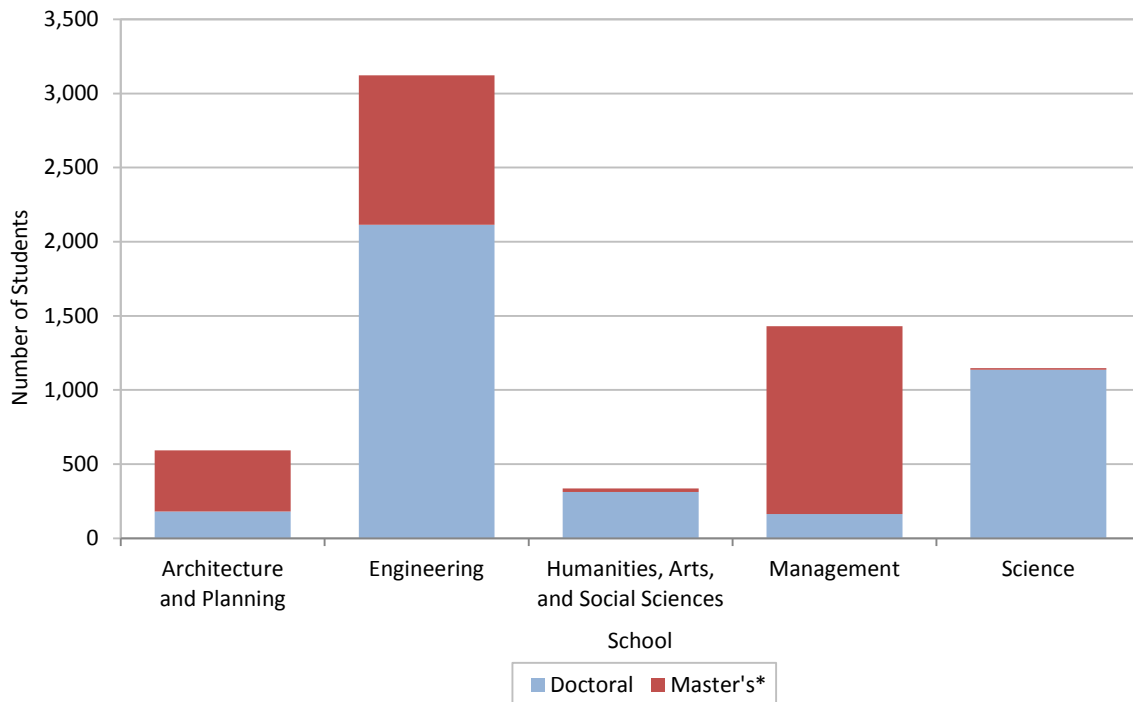
Citizenship	Count	Percentage
U.S. citizen	3,631	53.4
U.S. permanent resident	247	3.6
International	2,926	43.0
Total	6,804	100.0

Graduate Students by Gender, 2015–2016



Graduate Students by School, 2015–2016

School	Master's Count*	Doctoral Count	Total
Architecture and Planning	413	181	594
Engineering	1,009	2,114	3,123
Humanities, Arts, and Social Sciences	25	312	337
Management	1,266	164	1,430
Science	9	1,138	1,147
Total	2,722	3,909	6,631



*Excludes non-matriculating students

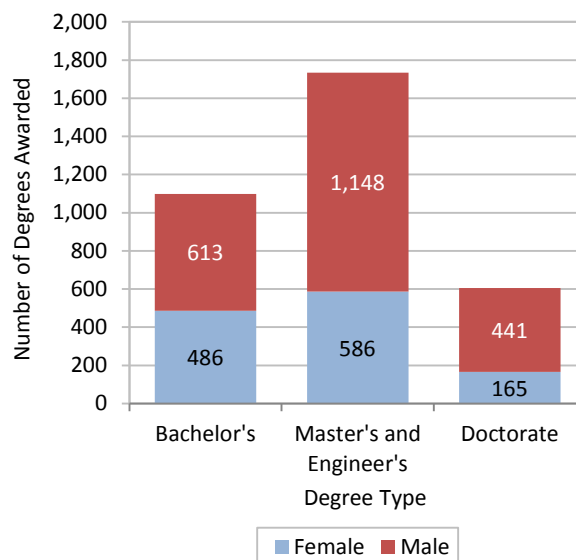
Degrees

In 2014–2015, MIT awarded 3,439 degrees.

Degrees Awarded by Type, 2014–2015

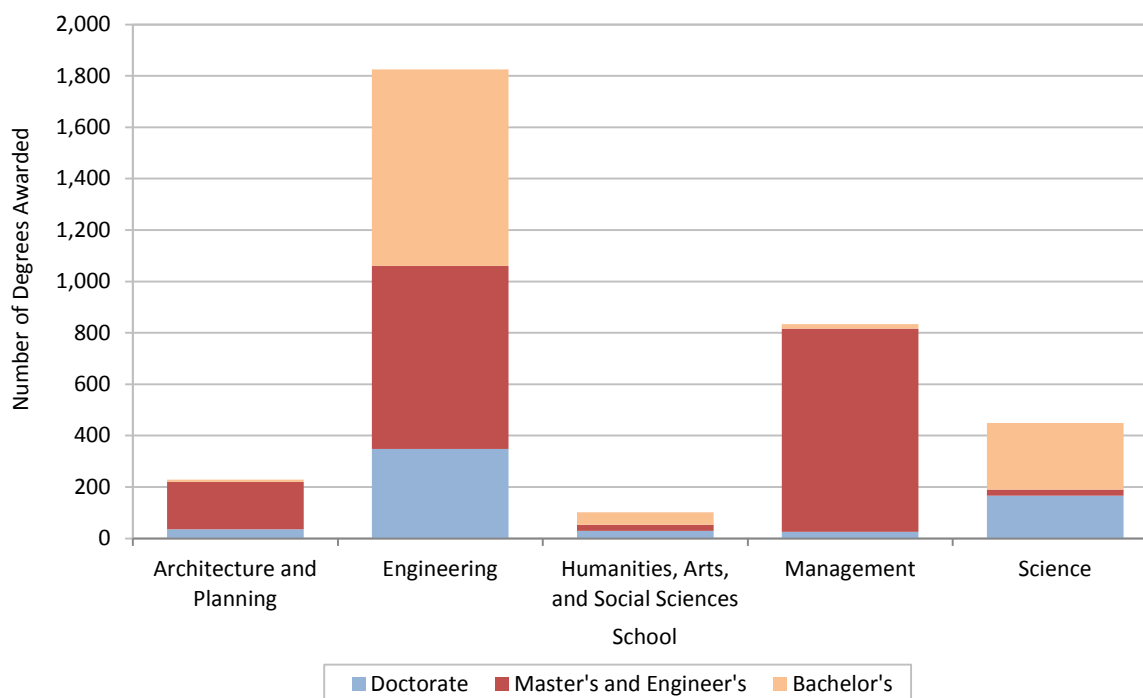
Degree Type	Count
Bachelor of Science degrees	1,099
Master of Science degrees	685
Master of Architecture, Master in City Planning, Master of Engineering, Master of Business Administration, and Master of Finance degrees	1,034
Engineer's degrees	15
Doctoral degrees	606

Degrees Awarded by Gender, 2014–2015



Degrees Awarded by School, 2014–2015

School	Bachelor's Count	Master's and Engineer's Count	Doctorate Count	Total
Architecture and Planning	9	184	36	229
Engineering	764	713	348	1,825
Humanities, Arts, and Social Sciences	49	24	29	102
Management	18	790	26	834
Science	259	23	167	449
Total	1,099	1,734	606	3,439



Alumni

In spring 2013, MIT invited over 5,900 undergraduate alumni from the classes of 2008, 2002, 1999, 1994, 1989, and 1984 to participate in a survey (<http://web.mit.edu/ir/surveys/alumni.html>) that asked them about their postgraduate education, their career, and their MIT undergraduate experience. The survey closed with a 36% response rate.

Seventy-five percent of alumni respondents said they have enrolled in a graduate or professional degree program since graduating from MIT. Of those who have enrolled in a graduate or professional degree program, over half did so immediately upon graduation. This includes students who earned a graduate degree simultaneously with their bachelor's degree. Eighty-five percent of respondents said they are employed either full-time or part-time. An additional 4% are unemployed and seeking employment. The remainder is either on leave or unemployed and not currently seeking employment. Among those respondents who are employed, 64% work in the for-profit sector, 13% work in government or military agencies, 14% work in the nonprofit sector, and 9% are self-employed. Twenty-two percent of respondents reported having started a company. Fourteen percent said they are currently developing a start-up company.

Service is a part of the lives of our alumni. Eighty-seven percent of respondents have served as an officer or on a committee for a local club, organization, or place of worship in the last 10 years. Thirty-seven percent have been a board member for a nonprofit organization. Seventy-three percent have done volunteer work at least once in the last year.

A fall 2012 survey of graduate alumni (http://web.mit.edu/ir/surveys/grad_alum.html) revealed that 93% of respondents are employed, with just 2% seeking employment (others are engaged in such activities as travel and caring for family). The average annual salary was reported to be \$156,793; the median was \$137,500. Graduate alumni, overall, were most likely to report working in a private for-profit organization (54%), in a U.S. four-year college or university (13%), or to be self-employed (9%). 3.8% were employed by the U.S. federal government; 0.4% by U.S. state government; and 0.7% in U.S. local government. A spirit of entrepreneurship flourishes, as 28% of all surveyed graduate alumni have started a company. Among doctoral alumni, 41% have at least one patent or invention.

MIT's 132,373 living alumni are connected to the Institute through graduating-class events, departmental organizations, and over 47 clubs in the United States and 42 abroad. More than 14,000 volunteers offer their time, financial support, and service on committees and on the MIT Corporation, the Institute's Board of Trustees. MIT graduates hold leadership positions in industries and organizations around the world. Over 21,000 alumni reside in Massachusetts, and about 86 percent of MIT's alumni live in the United States.

Undergraduate Financial Aid

Principles of MIT Undergraduate Financial Aid

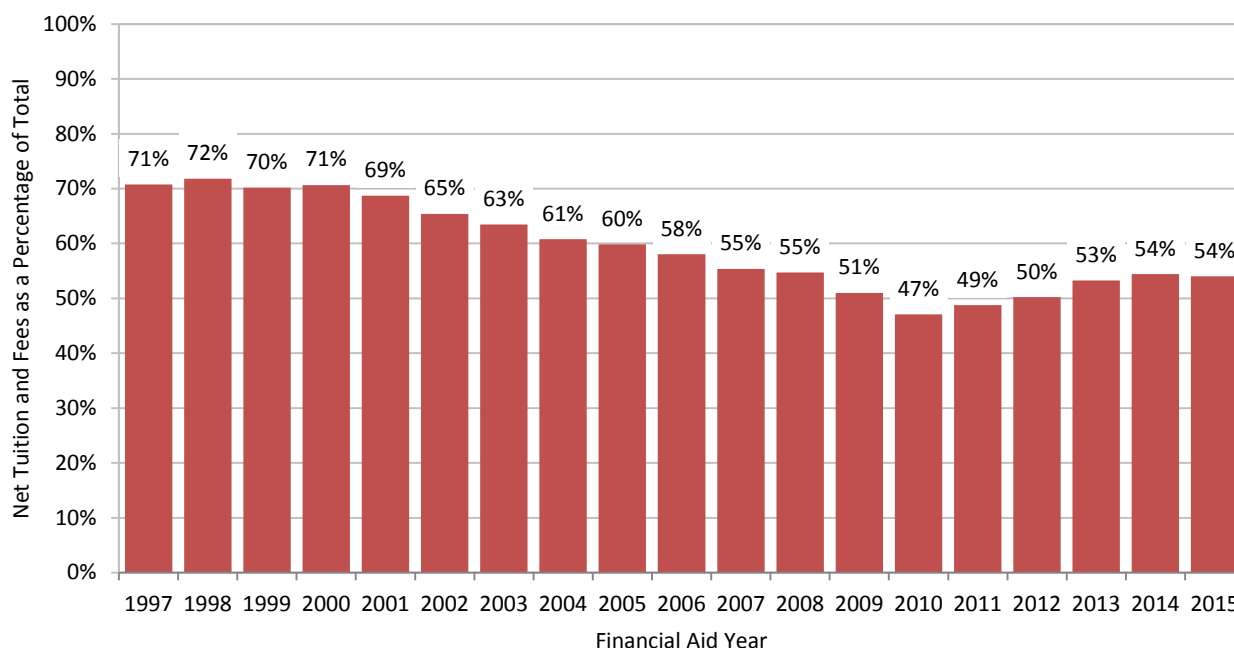
To ensure that MIT remains accessible to all qualified students regardless of their financial resources, MIT is committed to three guiding financial aid principles:

- Need-blind admissions: MIT recruits and enrolls the most talented and promising students without regard to their financial circumstances.

- Need-based financial aid: MIT awards aid only for financial need. It does not award undergraduate scholarships for academic or athletic achievements or for other non-financial criteria.
- Meeting the full need: MIT guarantees that each student’s demonstrated financial need is fully met.

As a result of these guiding principles, the Institute significantly discounts tuition.

**Net Undergraduate Tuition and Fees
as a Percentage of Total Tuition and Fees***



*Net tuition and fees calculated as a percentage of gross undergraduate tuition and fees received, minus MIT undergraduate scholarships.

Who Pays for an MIT Undergraduate Education

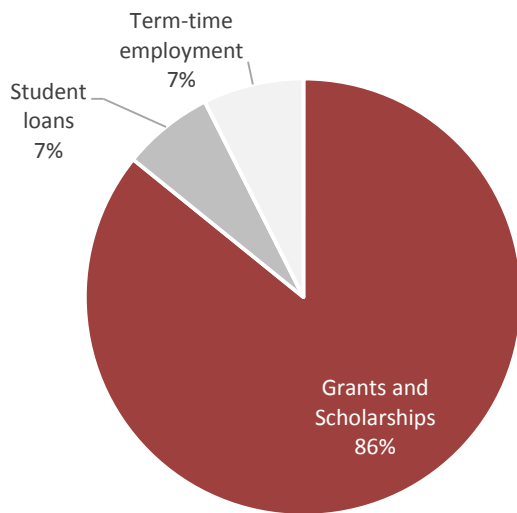
In 2014–2015, the annual price of an MIT education totaled \$61,530 per student—\$45,016 for tuition and fees, \$13,224 for room and board, an estimated \$2,790 for books, supplies, and personal expenses, and a per-student average of \$500 for travel. With 4,476 undergraduates enrolled, the collective price for undergraduates was \$275.4 million. Of this amount, families paid \$146.1 million, or 53 percent, and financial aid covered the remaining 47 percent, or \$129.3 million. Since MIT subsidizes the cost of educating undergraduates through its tuition pricing and continues to be the largest source of financial aid to its undergraduates, the Institute is the primary source for paying for an MIT undergraduate education, and families the secondary source.

Forms of Financial Undergraduate Aid

The primary form of financial aid to MIT undergraduates is grants or scholarships—terms that are used interchangeably, although grants are gift aid based on need and scholarships are gift aid based on merit. Since 2005–2006 the share of undergraduate aid in the form of grants/scholarships rose from 80.9 to 85.8 percent while the share in the form of student loans fell from 11.1 to 6.7 percent and term-time work decreased from 8.0 to 7.4 percent.

From the students’ perspective, grants are the sole form of aid that unambiguously increases the financial accessibility of college, since they don’t require repayment and don’t increase the students’ indebtedness. The preponderance of grant aid at MIT sets the Institute apart from other higher education institutions.

**Types of Financial Aid for MIT Undergraduates
2014–2015**



**Amounts of Financial Aid for
MIT Undergraduates, 2014–2015**

Aid Type	Amount (in U.S. Dollars)	Percentage
Grants and Scholarships	111,003,808	86
Student Loans	8,710,328	7
Term-time employment	9,623,864	7
Total	129,338,000	100

Sources of Undergraduate Financial Aid

In 2014–2015, MIT provided 77.1 percent of undergraduate financial aid. The federal government provided 11.7 percent, and the remaining 11.2 percent came from state and private resources. MIT differs here from the national trend of relying on the federal government as the largest source of financial aid.

Approximately 56 percent of MIT undergraduates received an MIT scholarship, averaging \$36,726 each. These scholarships come primarily from MIT’s endowed funds, gifts from alumni and friends, and general Institute funds.

MIT participates in the Federal Pell Grant Program, the Federal Direct Loan Program and the three campus-based programs: the Federal Supplemental

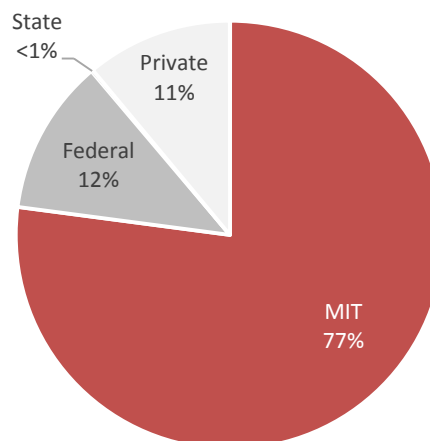
Educational Opportunity Grant, the Federal Perkins Loan Program, and the Federal Work-Study Program. Approximately 18 percent of MIT undergraduates receive a Pell Grant. MIT has participated in these programs since their inception and values their role in making an MIT education accessible to all qualified students. In addition, MIT undergraduates receive federal aid for their participation in the Air Force, Army, and Navy ROTC. ROTC aid is not based on need.

Students receive private scholarships in recognition of their academic accomplishments, athletic or musical skills, career interests, and many other criteria. Two states, in addition to Massachusetts, allow their residents to receive a state grant while attending MIT: Pennsylvania and Vermont. Most state grants are need-based.

Sources of Financial Aid for MIT Undergraduates
2014–2015

Sources of Financial Aid for
MIT Undergraduates, 2014–2015

Aid Source	Amount (in U.S. Dollars)	Percentage
MIT Financial Aid	99,710,485	77
Federal Financial Aid	15,154,350	12
State Financial Aid	174,078	0
Private Financial Aid	14,299,087	11
Total	129,338,000	100



The following table summarizes the sources and types of financial aid MIT undergraduates received in 2014–2015.

Undergraduate Financial Aid, 2014–2015

Source	Scholarships/Grants		Loans		Employment		Total*	
	Amount (\$)	Students	Amount (\$)	Students	Amount (\$)	Students	Amount (\$)	Students
MIT	91,852,488	2501	290,000	89	7,567,997	2556	99,710,485	3755
Federal	7,289,187	842	5,809,296	823	2,055,867	544	15,154,350	1704
State	174,078	91	N/A	N/A	N/A	N/A	174,078	91
Private	11,688,055	1327	2,611,032	118	N/A	N/A	14,299,087	1411
Total*	111,003,808	3138	8,710,328	946	9,623,864	3040	129,338,000	4072

*The total column and row are unduplicated numbers of students.

Graduate Financial Aid

Principles of MIT Graduate Financial Aid

MIT makes financial support available to graduate students from a variety of sources and in several different forms. Many forms of support are granted solely on the basis of merit (teaching and research assistantships; on-campus employment; some fellowships, scholarships, and traineeships), while others are granted on the basis of financial need (federal loans; some fellowships, scholarships, and traineeships; on-campus employment) or a combination of merit and need (some fellowships, scholarships, and traineeships; on-campus employment).

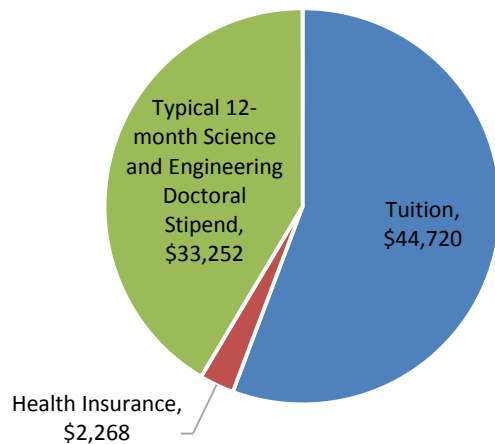
Tuition support, in particular, is provided to graduate and professional students in connection with research assistantships, teaching assistantships, and fellowship appointments. Tuition revenue support from MIT funds is considered financial aid but is not included in this report, as no singular office administers these sources of support.

A typical financial support package for a graduate student includes tuition, health insurance, and stipend support. The largest part of an MIT graduate student's expenses is dedicated to tuition (\$44,720 for the 2014–2015 academic year). Another portion (\$2,268) is dedicated to health insurance, unless a student already has comparable coverage. General living costs, including housing, food, transportation, and books, are largely covered by a stipend (approximately \$33,252 for a doctoral student). MIT houses approximately 36% of the graduate student body on campus, which contributes to keeping average housing costs at a reasonable level for graduate students within the context of the Boston area. The graduate residences also help foster a thriving on-campus graduate community that many graduate students cite as one of the most positive aspects of their time here.

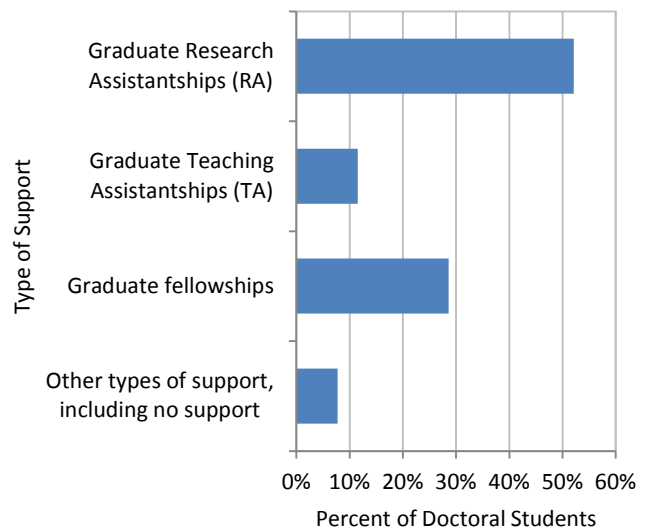
How Graduate Students are Supported

Enrollment is determined at the department and program level and departments and programs admit as many students as they can support based on their RA, TA, and fellowship resources as well as the number of faculty available to advise on research.

Graduate Student Financial Support, 2014–2015



Doctoral Graduate Student Support, 2014–2015



Forms of Graduate Financial Aid

Fellowships, Traineeships, and Scholarships

At MIT, fellowships and traineeships differ from scholarships. A fellowship award to a graduate student covers full or partial tuition, and also provides a stipend to help defray living expenses. In the context of graduate study, a scholarship covers full or partial tuition only. Although most awards are made on the basis of academic merit, financial need is a factor in some instances. Recipients of graduate financial aid must be enrolled as regular resident students. The Institute annually receives funds from individual and corporate donors for the support of fellowships and scholarships. In addition, government agencies and private foundations provide grants and fellowships—often directly to outstanding students—for use at institutions of the student’s choice. But occasionally these funds are directed to MIT for Institute designation of recipients.

For the fall semester 2014, the breakdown of funding sources for students that were primarily supported by fellowships were as follows:

Sponsor	Count
Department of Defense	89
Department of Energy	22
National Institutes of Health	32
NASA	24
National Science Foundation	199
Other Federal Agencies	1
Other U.S. sources	43
Non-U.S. sources	100
MIT Internal	1,303
Total	1,813

Teaching Assistantships

MIT employs about 1,160 graduate students each year as part-time or full-time teaching assistants to assist the faculty in grading, instructing in the classroom and laboratory, and conducting tutorials. Teaching assistants receive stipends as well as tuition support for the services that they provide.

Appointments to teaching assistantships are made upon recommendation of the head of a department. Only full-time graduate students who are candidates for advanced degrees may be appointed, and the Free Application for Federal Student Aid (FAFSA) is required for all teaching assistants who are U.S. citizens or permanent residents.

Research Assistantships

Each year about 3,600 graduate students at MIT hold appointments as research assistants. The principal duty of a research assistant is to contribute to a program of departmental or interdepartmental research. Research assistants receive stipends as well as tuition support for the services that they provide, and are compensated on the basis of time devoted to their research.

Students who receive financial support from other sources (fellowships, scholarships, etc.) may receive supplementary stipends as teaching or research assistants in accordance with Institute and departmental guidelines.

Self-Support

Graduate and professional students are eligible for need-based financial aid, including student loans, as well as student employment under the Federal Work-Study Program, both of which are administered and reported by MIT Student Financial Services (SFS). Graduate student employment earnings under the Federal Work-Study Program, including on- and off-campus programs, totaled \$0.9 million in 2014–2015, with 0.78 percent of graduate and professional students (52 students) earning \$17,458 on average.

In AY2015, graduate students borrowed loans that totaled \$43.3 million, a decrease of approximately \$1.6 million from the prior year, with 11.2 percent of graduate and professional students (741 students) borrowing an average of \$58,471.

Section 4

Campus Research

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Research Support

MIT has historically viewed teaching and research as inseparable parts of its academic mission. Therefore, the Institute recognizes its obligation to encourage faculty to pursue research activities that hold the greatest promise for intellectual advancement. MIT maintains one of the most vigorous programs of research of any university and conducts basic and applied research principally at two Massachusetts locations, the MIT campus in Cambridge and MIT Lincoln Laboratory, a federally funded research and development center in Lexington.

MIT pioneered the federal/university research relationship, starting in World War II. Initially called upon by the federal government to serve the national war effort, that relationship has continued into the present day, helping MIT fulfill its original mission of serving the nation and the world.

Research Expenditures (MIT FY2015)

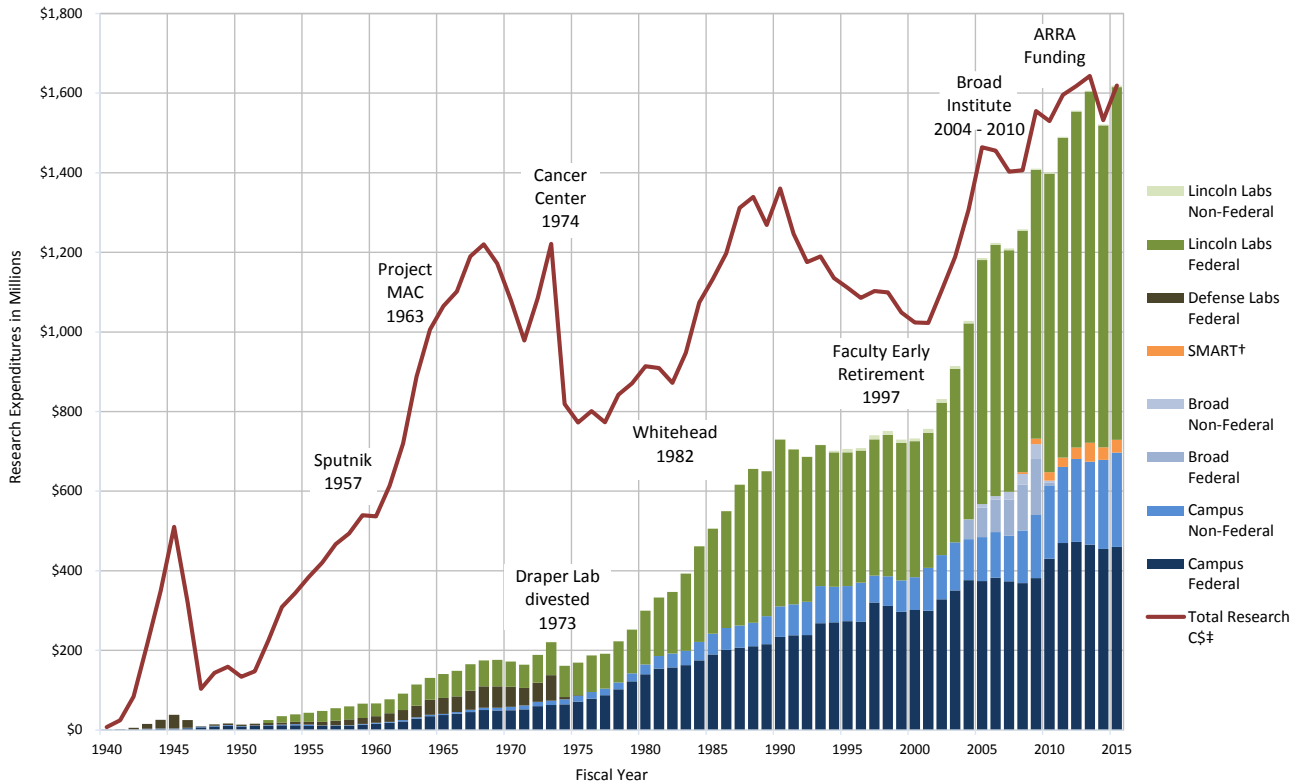
Cambridge Campus	\$696.9 million
Lincoln Laboratory*	\$890.2 million
SMART*	\$31.9 million
Total	\$1,619.0 million

*Totals do not include research performed by campus laboratories for Lincoln Laboratory and Singapore-MIT Alliance for Research and Technology (SMART).

All federal research on campus is awarded competitively based on the scientific and technical merit of the proposals. In FY2015, there were 2,723 active awards and 396 members of research consortiums.

Research activities range from individual projects to large-scale, collaborative, and sometimes international endeavors. Peer-reviewed research accomplishments form a basis for reviewing the qualifications of prospective faculty appointees and for evaluations related to promotion and tenure decisions.

**MIT Research Expenditures
1940–2015**



†SMART: Singapore-MIT Alliance for Research and Technology

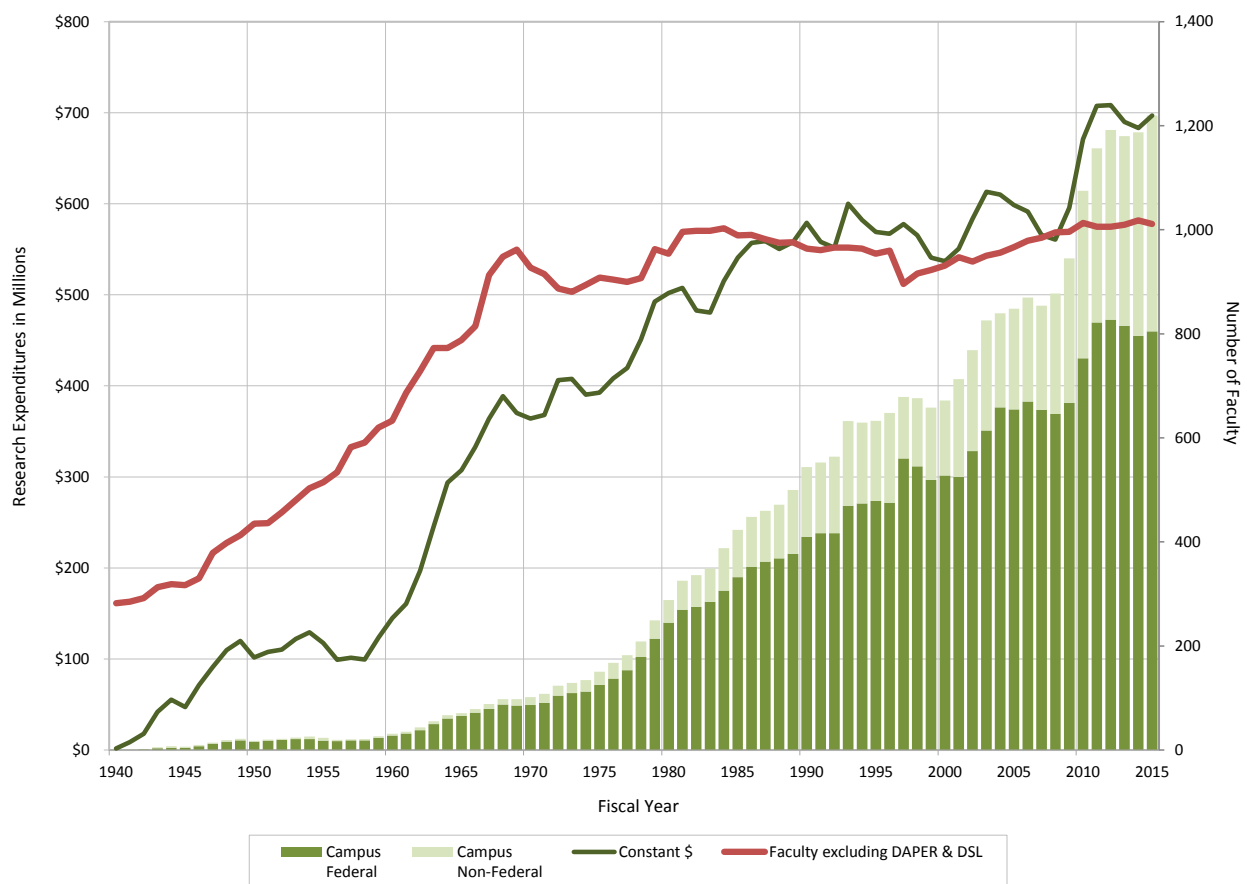
‡Total Research constant dollars are calculated using the Consumer Price Index for all Urban Consumers weighted with fiscal year 2015 equaling 100.

The Institute provides the faculty with the infrastructure and support necessary to conduct research, much of it through contracts, grants, and other arrangements with government, industry, and foundations. The Office of Sponsored Programs provides central support related to the administration of sponsored research programs, and it assists faculty, other principal investigators, and their local administrators in managing and identifying resources for individual sponsored projects. In addition, a Research Council—which is chaired by the Vice President for Research and composed of the heads of all major research laboratories and centers that report to the Vice President for Research—addresses research policy and administration issues.

The Resource Development Office is available to work with faculty to generate proposals for foundation or other private support.

The Institute sees profound merit in a policy of open research and free interchange of information among scholars. At the same time, MIT is committed to acting responsibly and ethically in all its research activities. As a result, MIT has policies related to the suitability of research projects, research conduct, sources of support, use of human subjects, sponsored programs, relations with intelligence agencies, the acquisition of art and artifacts, the disposition of equipment, and collaborations with research-oriented industrial organizations. These policies are spelled out on the Policies and Procedures website and on the Office of Sponsored Programs website.

**Campus Research Expenditures and Faculty
Excluding Broad and Defense Labs
1940–2015**



DAPER: Department of Athletics, Physical Education and Recreation
DSL: Division of Student Life

Campus Research Sponsors

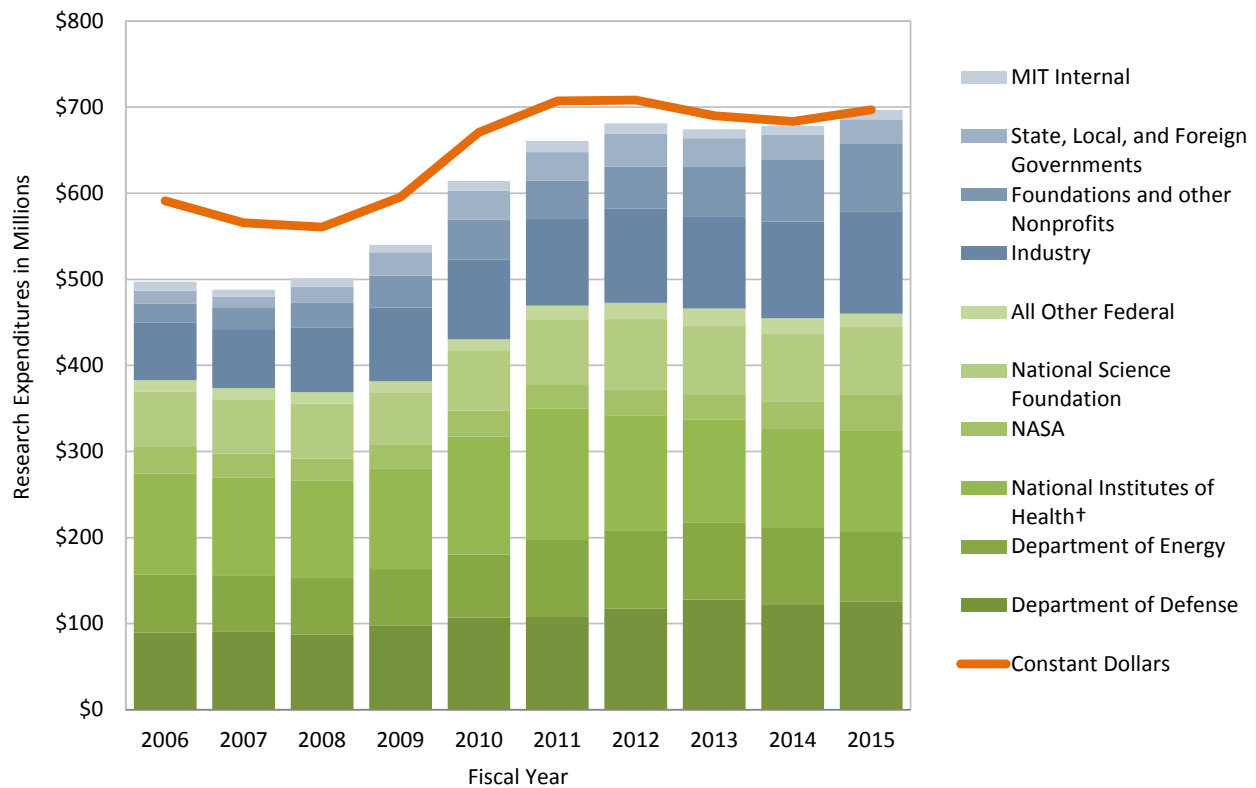
The tables and charts for campus research expenditures below, and on the following pages, show the amount MIT expended by fiscal year (July 1–June 30). These figures do not include expenditures for MIT Lincoln Laboratory. Information for Lincoln

Laboratory begins on page 79. Expenditures funded by industrial sponsors are shown on page 95 in the MIT and Industry section. Federal research expenditures include all primary contracts and grants, including sub-awards from other organizations where the federal government is the original funding source.

**Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2006–2015**

	2006	2007	2008	2009	2010
Federal	382,784,774	373,603,371	369,008,780	381,459,466	430,154,479
Non-federal	114,361,780	114,389,201	132,487,316	158,595,887	184,216,417
Total	497,146,554	487,992,571	501,496,096	540,055,353	614,370,896
Constant dollars*	591,295,439	565,776,227	560,656,987	595,451,903	670,897,854

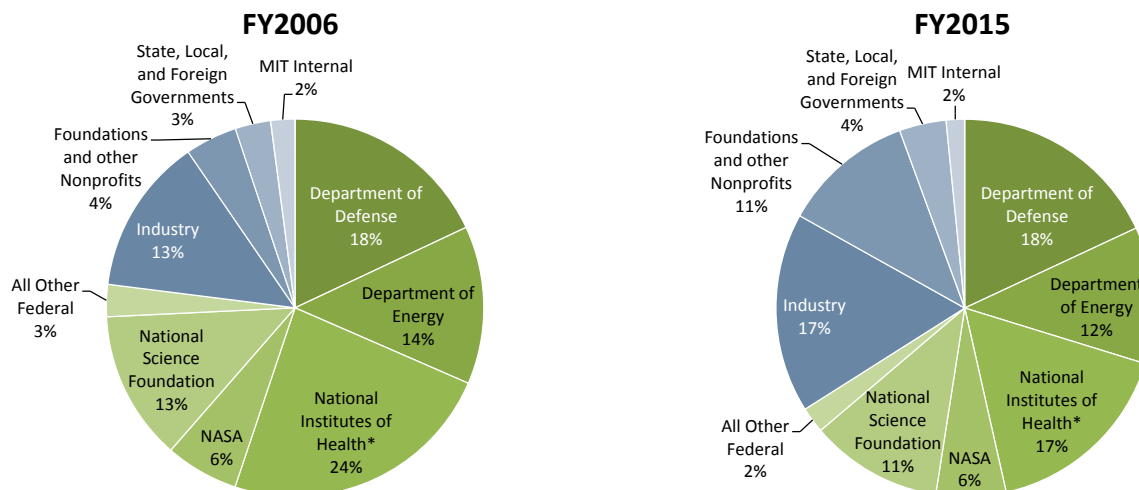
	2011	2012	2013	2014	2015
Federal	469,520,579	472,582,743	465,946,679	454,938,599	459,979,141
Non-federal	191,304,692	208,496,567	208,401,668	223,473,071	236,912,028
Total	660,825,271	681,079,310	674,348,348	678,411,670	696,891,169
Constant dollars*	707,421,238	708,349,648	689,867,045	683,350,357	696,891,169



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

†National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 1% of expenditures per year.

Campus Research Expenditures by Primary Sponsor



Campus Research Expenditures by Primary Sponsor

Primary Sponsor	FY2015 (In U.S. Dollars)	Percent of Campus Total
Department of Defense	125,853,521	18
Department of Energy	81,528,299	12
National Institutes of Health*	116,469,457	17
NASA	41,739,692	6
National Science Foundation	78,952,919	11
All other federal	15,435,252	2
Total Federal	459,979,141	66
Industry	119,238,077	17
Foundations and other nonprofit	78,666,639	11
State, local, and foreign governments	27,951,041	4
MIT internal	11,056,271	2
Total Non-Federal	236,912,028	34
Campus Total	696,891,169	100

*National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 1% of expenditures per year.

Department of Defense

Selected Projects

For stronger, lighter, cheaper materials, scroll up

Water filters of the future may be made from billions of tiny, graphene-based nanoscrolls. Each scroll, made by rolling up a single, atom-thick layer of graphene, could be tailored to trap specific molecules and pollutants in its tightly wound folds. Billions of these scrolls, stacked layer by layer, may produce a lightweight, durable, and highly selective water purification membrane.

But there's a catch: Graphene does not come cheap in its pure, unblemished form. Seeking an alternative, a team of researchers is looking to graphene oxide—graphene's much cheaper, imperfect form. The team fabricated nanoscrolls made from graphene oxide flakes and was able to control the dimensions of each nanoscroll, using both low- and high-frequency ultrasonic techniques. The scrolls have mechanical properties that are similar to graphene, and they can be made at a fraction of the cost, the researchers say.

Graduate student Itai Stein and Carlo Amadei, a graduate student at Harvard University, have published their results in the journal *Nanoscale*. This work was supported, in part, by the Department of Defense through the National Defense Science and Engineering Graduate (NDSEG) fellowship program.

<http://bit.ly/1raCpyJ>

Rogue wave ahead

Sailing history is rife with tales of monster-sized rogue waves—huge, towering walls of water that seemingly rise up from nothing to dwarf, then deluge, vessel and crew. Rogue waves can measure eight times higher than the surrounding seas and can strike in otherwise calm waters, with virtually no warning.

A prediction tool developed by MIT engineers may give sailors a 2-3 minute warning of an incoming rogue wave, providing them with enough time to shut down essential operations on a ship or offshore platform. The tool, in the form of an algorithm, sifts through data from surrounding waves to compute a probability that the wave group will turn into a rogue wave within the next few minutes.

To understand and predict rare events such as rogue waves, scientists have typically taken a leave-no-wave-behind approach. This extremely detailed approach is computationally expensive, as it requires a cluster of computers to solve equations for each and every wave, and their interactions with surrounding waves. Themis Sapsis and former postdoc Will Cousins have devised a much simpler, faster way to predict rogue waves, given data on the surrounding wave field.

Sapsis and Cousins have published their results in the *Journal of Fluid Mechanics*. This research was supported, in part, by the Office of Naval Research, the Army Research Office, and the American Bureau of Shipping.

<http://bit.ly/1THUakf>

Breaking through the bacteria barrier

Genetically engineering any organism requires first getting its cells to take in foreign DNA. To do this, scientists often perform a process called electroporation, in which they expose cells to an electric field. If that field is at the right magnitude, it will open up pores within the cell membrane, through which DNA can flow. It can take scientists months or even years to figure out the exact electric field conditions to reversibly unlock a membrane's pores.

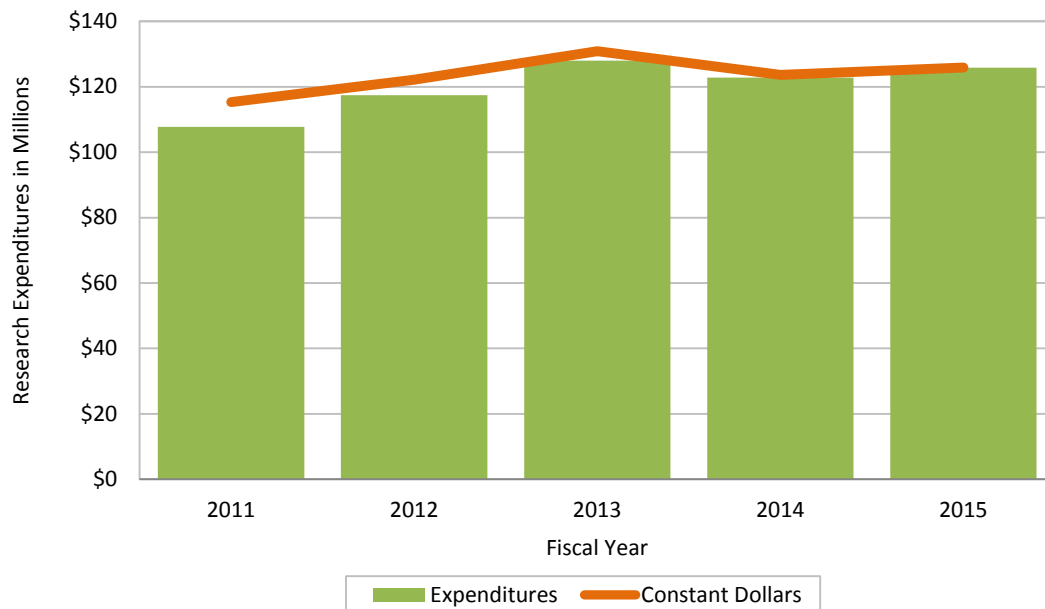
A new microfluidic device developed by MIT engineers may help scientists quickly home in on the electric field "sweet spot"—the range of electric potentials that will be strong enough to puncture the membrane temporarily, but not so strong as to do so permanently, which would cause a cell to die. In principle, the simple device could be used on any microorganism or cell, significantly speeding up the first step in genetic engineering.

Cullen Buie and his colleagues, including postdoc Paulo Garcia, graduate student Zhifei Ge, and lecturer Jeffrey Moran, have published their results in the journal *Scientific Reports*. This research was supported, in part, by DARPA and the National Science Foundation.

<http://bit.ly/1pHbr00>

**Department of Defense Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	107,753,196	117,457,789	127,966,747	122,761,059	125,853,521
Constant dollars*	115,351,066	122,160,785	130,911,630	123,654,733	125,853,521



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**

(Shown in descending order of expenditures)

- Research Laboratory of Electronics
- Computer Science and Artificial Intelligence Laboratory
- Institute for Soldier Nanotechnologies
- Biological Engineering
- Mechanical Engineering
- Sociotechnical Systems Research Center
- Laboratory for Information and Decision Systems
- Chemistry
- Aeronautics and Astronautics
- Microsystems Technology Laboratories

In fall 2014, the Department of Defense funded the primary appointments of graduate students with 291 research assistantships and 89 fellowships.

Twenty-eight current faculty and staff have received the Office of Naval Research Young Investigator Program Award.

Department of Energy

Selected Projects

New chemistries found for liquid batteries

Liquid metal batteries, invented by Donald Sadoway and his students a decade ago, are a promising candidate for making renewable energy more practical by storing large amounts of energy and thus even out the ups and downs of power production and power use. Now, Sadoway and his team have found yet another set of chemical constituents that could make the technology even more practical and affordable, and open up a whole family of potential variations that could make use of local resources.

The latest findings are reported in the journal *Nature Communications*, in a paper by Sadoway and postdoc Takanari Ouchi, along with Hojong Kim (now a professor at Penn State University) and PhD student Brian Spatocco. They show that calcium, an abundant and inexpensive element, can form the basis for both the negative electrode layer and the molten salt that forms the middle layer of the three-layer battery. The research was supported by the U.S. Department of Energy's Advanced Research Projects Energy (ARPA-E) and by the French energy company Total S.A.

<http://bit.ly/23BLpbW>

Carbon nanotubes improve metal's longevity under radiation

One of the main reasons for limiting the operating lifetimes of nuclear reactors is that metals exposed to the strong radiation environment near the reactor core become porous and brittle, which can lead to cracking and failure. A team of researchers at MIT and elsewhere has found that, at least in some reactors, adding a tiny quantity of carbon nanotubes to the metal can dramatically slow this breakdown process.

Helium from radiation transmutation takes up residence inside metals and causes the material to become riddled with tiny bubbles along grain boundaries and progressively more brittle, the researchers explain. The nanotubes, despite only making up a small fraction of the volume—less than 2 percent—can form a percolating, one-dimensional transport

network, to provide pathways for the helium to leak back out instead of being trapped within the metal, where it could continue to do damage.

The findings are described in the journal *Nano Energy*, in a paper by Ju Li, postdocs Kang Pyo So and Mingda Li, research scientist Akihiro Kushima, and 10 others at MIT, Texas A&M University, and universities in South Korea, Chile, and Argentina. The work was supported by the U.S. Department of Energy and the National Research Foundation of Korea.

<http://bit.ly/1WkAvZC>

New finding may explain heat loss in fusion reactors

One of the biggest obstacles to making fusion power practical—and realizing its promise of virtually limitless and relatively clean energy—has been that computer models have been unable to predict how the hot, electrically charged gas inside a fusion reactor behaves under the intense heat and pressure required to make atoms stick together. A long-standing discrepancy between predictions and observed results in test reactors has been called “the great unsolved problem” in understanding the turbulence that leads to a loss of heat in fusion reactors. Solving this discrepancy is critical for predicting the performance of new fusion reactors.

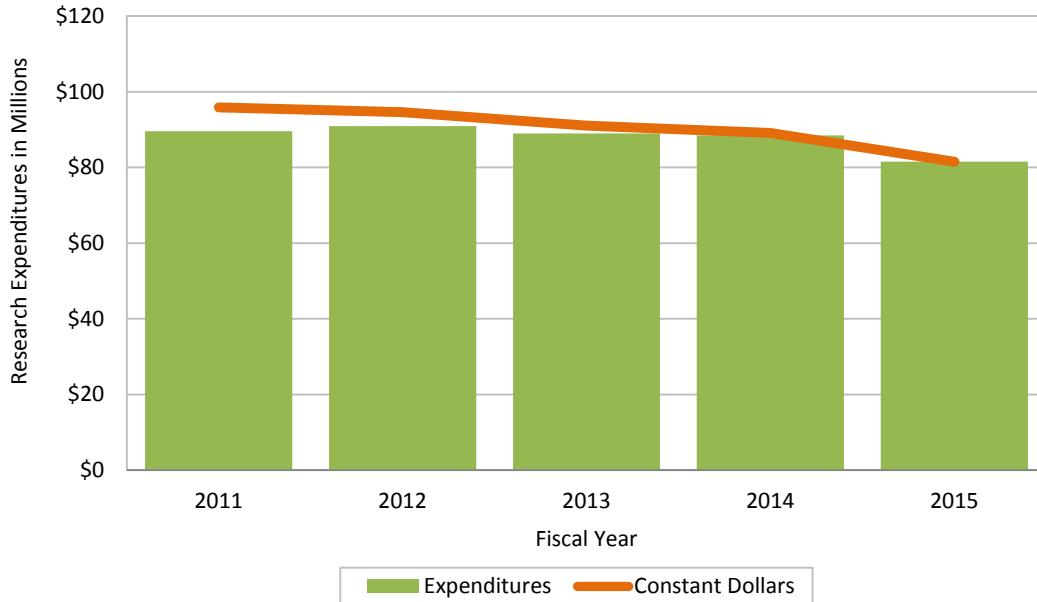
Researchers at MIT's Plasma Science and Fusion Center, in collaboration with others at the University of California at San Diego, General Atomics, and the Princeton Plasma Physics Laboratory, say that they have found the key. For the first time, researchers show two types of turbulence within plasma that cause significant heat loss. It turns out that interactions between turbulence of electrons and of ions, can account for the mysterious mismatch between theory and experimental results.

The new findings are detailed in a pair of papers published in the journals *Nuclear Fusion* and *AIP Physics of Plasmas*, by research scientist Nathan Howard, doctoral student Juan Ruiz Ruiz, Anne White, and 12 collaborators. The research was supported by the U.S. Department of Energy.

<http://bit.ly/1SzmviX>

**Department of Energy Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	89,562,126	90,940,035	88,987,983	88,450,656	81,528,299
Constant dollars*	95,877,311	94,581,264	91,035,853	89,094,557	81,528,299



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**

(Shown in descending order of expenditures)

- Plasma Science and Fusion Center
- Laboratory for Nuclear Science
- Mechanical Engineering
- Chemical Engineering
- Nuclear Science and Engineering
- Research Laboratory of Electronics
- Materials Science and Engineering
- Materials Processing Center
- Nuclear Reactor Laboratory
- Chemistry

In fall 2014, the Department of Energy funded the primary appointments of graduate students with 191 research assistantships and 22 fellowships.

Twenty-five current faculty have received the Department of Energy Outstanding Junior Investigator award or Early Career Research Program Award.

National Institutes of Health

Selected Projects

A new paper-based test for the Zika virus

A test developed at MIT and other institutions can diagnose Zika virus infection within a few hours. The test can be stored at room temperature and read with a simple electronic reader, making it potentially practical for widespread use. The new device is based on technology that James Collins and colleagues previously developed to detect the Ebola virus.

Currently, patients are diagnosed by testing whether they have antibodies against Zika in their bloodstream, or by looking for pieces of the viral genome in a patient's blood sample. However, these tests can take days or weeks to yield results, and the antibody test cannot discriminate accurately between Zika and dengue. The researchers showed that the new device can make this distinction and detect viral RNA concentrations as low as 2 or 3 parts per quadrillion.

Collins and colleagues from MIT and Harvard University's Wyss Institute for Biologically Inspired Engineering and other institutions described the new device in the online edition of *Cell*. The research was funded by the Wyss Institute for Biologically Inspired Engineering, MIT's Center for Microbiome Informatics and Therapeutics, the Defense Threat Reduction Agency, and the National Institutes of Health.

<http://bit.ly/1SUZ8ZK>

Engineers develop a pill for long-term drug release

Researchers from MIT and Brigham and Women's Hospital have designed a new type of pill that, once swallowed, can attach to the lining of the gastrointestinal tract and slowly release its contents. The tablet is engineered so that one side adheres to tissue, while the other repels food and liquids that would pull it away from the attachment site. Such extended-release pills could be used to reduce the dosage frequency of some drugs, the researchers say. For example, antibiotics that normally have to be taken two or three times a day could be given just once, making it easier for patients to stick to their dosing schedule.

Giovanni Traverso, a research affiliate at MIT's Koch Institute for Integrative Cancer Research, a gastroenterologist at Brigham and Women's Hospital, is one of the senior authors of a paper describing the device

in the journal *Advanced Healthcare Materials*. Robert Langer is also a senior author of the paper. The research was funded by the Bill and Melinda Gates Foundation, the National Institutes of Health, and the Alexander von Humboldt Foundation.

<http://bit.ly/1StoInj>

Why some tumors withstand treatment

New cancer drugs allow doctors to tailor treatment based on the genetic profile of a patient's tumor. However, these drugs don't work at all in some patients, and they lose their effectiveness in others. A study from MIT and Massachusetts General Hospital (MGH) reveals why a certain class of these drugs, known as kinase inhibitors, doesn't always halt tumor growth.

The researchers found that while kinase inhibitors successfully shut down their targets, they also provoke cells to turn on a backup system that can take over for the one knocked out by the drug. The researchers showed that certain proteins can be detected in blood samples from patients, and that high protein levels show if there is a lot of potential for the backup system to kick in, and kinase inhibitors to not be effective. The team also showed that disrupting both systems with a combination of drugs yields much better results, in a study of mice.

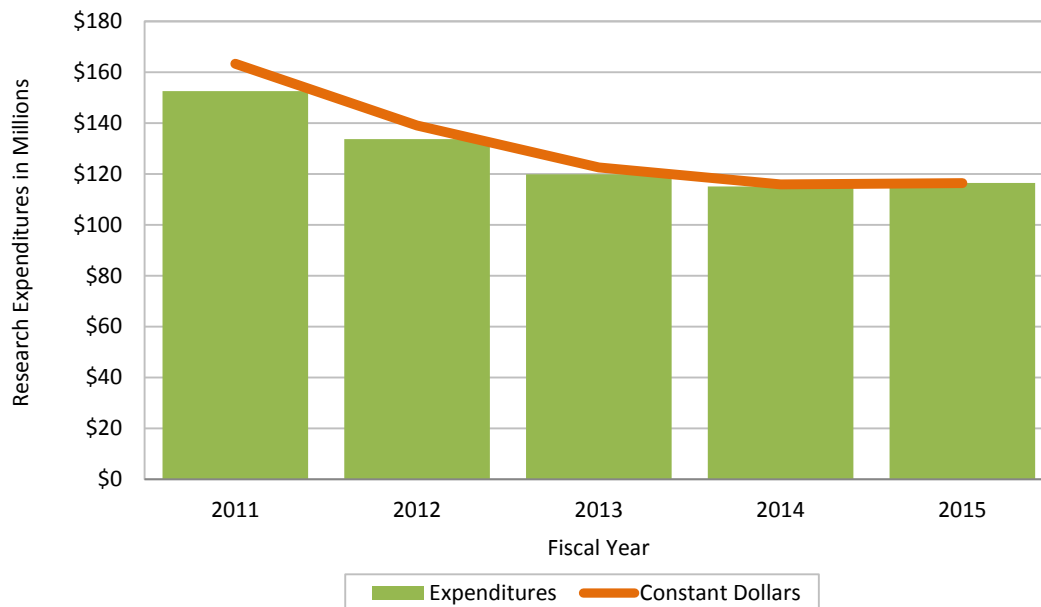
"The discovery seems to identify those patients who will go on to receive long-term clinical benefit versus those whose tumors will quickly adapt and circumvent treatment, by virtue of a blood-based test that can be performed at baseline or within days of initiating treatment," says Keith Flaherty, an author of the paper and director of developmental therapeutics at the MGH Cancer Center, who hopes to begin performing this kind of test in patients.

Douglas Lauffenburger is the senior author of the study, which appears in online edition of *Cancer Discovery*. The lead authors are Miles Miller, a former graduate student who is now a postdoc at Harvard Medical School, and Madeleine Oudin, a Koch Institute postdoc. The research was funded by the National Cancer Institute Centers for Cancer Systems Biology program.

<http://bit.ly/1Obsd30>

**National Institutes of Health Campus Research Expenditures (in U.S. Dollars)*
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	152,664,013	133,687,332	119,908,451	115,074,564	116,469,457
Constant dollars†	163,428,625	139,040,157	122,667,889	115,912,281	116,469,457



*National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 1% of expenditures per year.

†Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**

(Shown in descending order of expenditures)

- Koch Institute for Integrative Cancer Research
- Biology
- Biological Engineering
- Picower Institute for Learning and Memory
- Chemistry
- McGovern Institute for Brain Research
- Computer Science and Artificial Intelligence Laboratory
- Center for Environmental Health Sciences
- Research Laboratory of Electronics
- Institute for Medical Engineering and Science

In fall 2014, the National Institutes of Health and other Department of Health and Human Services programs funded the primary appointments of graduate students with 167 research assistantships and 32 fellowships.

Ten current faculty or staff have received the NIH Director’s Pioneer Award. The recipients are Edward Boyden, Emery Brown, Arup Chakraborty, James Collins, Hidde Ploegh, Aviv Regev, Leona Samson, Alice Ting, Mehmet Yanik, and Feng Zhang.

NASA

Selected Projects

First temperature map of a “super-Earth” reveals lava world

Astronomers from MIT, Cambridge University, and elsewhere have generated the first temperature map of a “super-Earth” exoplanet, revealing an inhospitable world covered in rivers and lakes of boiling hot magma. Temperatures on the planet are so high that any atmosphere is likely to have been burned off or vaporized into space. The results are published in the journal *Nature*.

The planet, named 55 Cancri e, resides in the constellation Cancer, at a relatively close 40 light years from Earth. It’s thought to have a rocky, rather than gaseous, composition, and at roughly twice the size of our planet, it is considered a super-Earth. 55 Cancri e is essentially a heat-seeking fireball, orbiting extremely close to its star. It circles in just 18 hours. The new temperature map shows that it’s scorching orbit can’t explain its blistering heat; in fact, the planet may be boiling from the inside out.

The scientists, including postdoc Julien de Wit and led by former postdoc Brice-Olivier Demory, generated the temperature map from observations of the planet made by NASA’s Spitzer Space Telescope. The Spitzer Space Telescope is operated by the Jet Propulsion Laboratory (JPL) and Caltech, under contract to NASA. Support for this work was provided by JPL/Caltech.

<http://bit.ly/1UjMJ2x>

Most distant massive galaxy cluster identified

Astronomers at MIT, the University of Missouri, the University of Florida, and elsewhere, have detected a massive, sprawling, churning galaxy cluster that formed only 3.8 billion years after the Big Bang. Located 10 billion light years from Earth and potentially comprising thousands of individual galaxies, the megastructure is about 250 trillion times more massive than the sun, or 1,000 times more massive than the Milky Way galaxy. The cluster, named IDCS

J1426.5+3508 (or IDCS 1426), is the most massive cluster of galaxies yet discovered in the first 4 billion years after the Big Bang.

In 2012, scientists using NASA’s Spitzer Space Telescope first detected signs of IDCS 1426 and made some initial estimates of its mass. To get a more precise estimate of the galaxy cluster’s mass, Michael McDonald and his colleagues used data from several of NASA’s Great Observatories: the Hubble Space Telescope, the Keck Observatory, and the Chandra X-ray Observatory.

McDonald and his colleagues presented their results at the 227th American Astronomical Society meeting in Kissimmee, Florida. Their findings will also be published in *The Astrophysical Journal*. This research was funded, in part, by NASA.

<http://bit.ly/1Xuz5uj>

NASA gives MIT a humanoid robot to develop software for future space missions

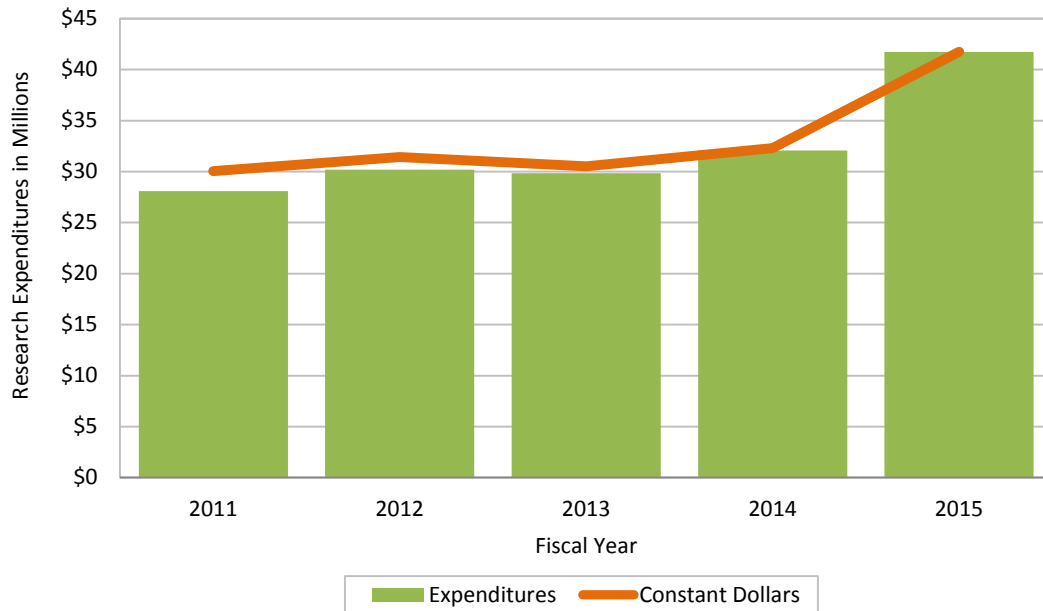
MIT’s Computer Science and Artificial Intelligence Laboratory (CSAIL) is one of two university research groups nationwide that will receive a 6-foot, 290-pound humanoid robot from NASA to test and develop for future space missions to Mars and beyond. A group led by CSAIL principal investigator Russ Tedrake will develop algorithms for the robot, known as “Valkyrie” or “R5,” as part of NASA’s upcoming Space Robotics Challenge, which aims to create more dexterous autonomous robots that can help or even take the place of humans “extreme space” missions. (NASA’s challenge is divided into a virtual competition using robotic simulations, and a physical competition using the robot.)

Tedrake’s team, which was selected from groups that were entered in the Defense Advanced Research Projects Agency (DARPA) Robotics Challenge, will receive as much as \$250,000 a year for two years from NASA’s Space Technology Mission Directive.

<http://bit.ly/1QLq64L>

**NASA Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	28,079,693	30,203,575	29,834,713	32,062,601	41,739,692
Constant dollars*	30,059,642	31,412,923	30,521,295	32,296,010	41,739,692



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**
(Shown in descending order of expenditures)

- Kavli Institute for Astrophysics and Space Research
- Earth, Atmospheric and Planetary Sciences
- Aeronautics and Astronautics
- Haystack Observatory
- Center for Global Change Science
- Media Laboratory
- Civil and Environmental Engineering
- Research Laboratory of Electronics
- Laboratory for Manufacturing and Productivity
- Microsystems Technology Laboratories

In fall 2014, NASA funded the primary appointments of graduate students with 53 research assistantships and 24 fellowships.

National Science Foundation

Selected Projects

First-ever 3D printed robots made of both solids and liquids

In a new paper, researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) present the first-ever technique for 3D printing robots that involves printing solid and liquid materials at the same time. The new method allows the team to automatically 3D print dynamic robots in a single step, with no assembly required, using a commercially-available 3D printer. To demonstrate the concept, researchers 3D printed a tiny six-legged robot that can crawl via 12 hydraulic pumps embedded within its body. They also 3D printed robotic parts that can be used on existing platforms, such as a soft rubber hand for the Baxter research robot.

"Our approach, which we call 'printable hydraulics,' is a step towards the rapid fabrication of functional machines," says CSAIL Director Daniela Rus, who oversaw the project and co-wrote the paper. "All you have to do is stick in a battery and motor, and you have a robot that can practically walk right out of the printer."

The paper, which was accepted to IEEE International Conference on Robotics and Automation (ICRA), was co-written by postdoc Robert MacCurdy and PhD candidate Robert Katzschmann, as well as Harvard University undergraduate Youbin Kim. The team's work was funded, in part, by a grant from the National Science Foundation.

<http://bit.ly/1PWf6wP>

Gravitational waves detected 100 years after Einstein's prediction

For the first time, scientists have observed ripples in the fabric of spacetime called gravitational waves, arriving at the Earth from a cataclysmic event in the distant universe. This confirms a major prediction of Albert Einstein's 1915 general theory of relativity.

Gravitational waves carry information about their dramatic origins and about the nature of gravity that cannot otherwise be obtained. Physicists have

concluded that the detected gravitational waves were produced during the final fraction of a second of the merger of two black holes to produce a single, more massive spinning black hole. This collision of two black holes had been predicted but never observed.

The gravitational waves were detected on September 14, 2015 at 5:51 a.m. Eastern Daylight Time (09:51 UTC) by both of the twin Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors, located in Livingston, Louisiana, and Hanford, Washington, USA. The LIGO Observatories are funded by the National Science Foundation (NSF), and were conceived, built, and are operated by Caltech and MIT. The discovery, accepted for publication in the journal *Physical Review Letters*, was made by the LIGO Scientific Collaboration (which includes the GEO Collaboration and the Australian Consortium for Interferometric Gravitational Astronomy) and the Virgo Collaboration using data from the two LIGO detectors.

<http://bit.ly/20XHkPE>

Machines that learn like people

Object-recognition systems are beginning to get pretty good. But object-recognition systems are typically trained on millions of visual examples, which is a far cry from how humans learn. Show a human two or three pictures of an object, and he or she can usually identify new instances of it.

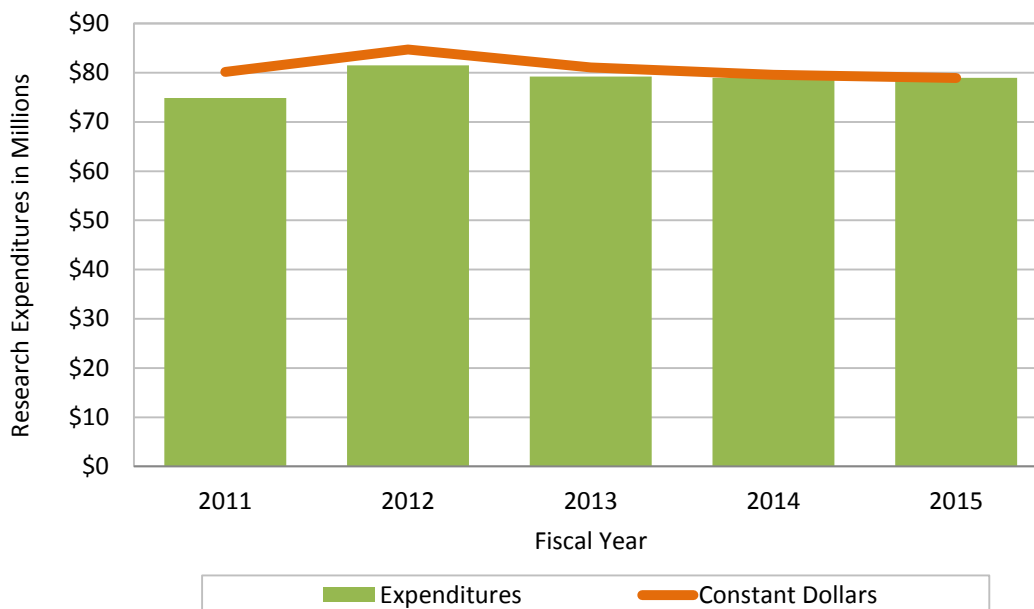
Four years ago, Tomaso Poggio's group at MIT's McGovern Institute for Brain Research began developing a new computational model of visual representation, intended to reflect what the brain actually does. In the journal *Theoretical Computer Science*, the researchers prove that a machine-learning system based on their model could indeed make highly reliable object discriminations on the basis of just a few examples. In both that paper and another that appeared in *PLOS Computational Biology*, they show that aspects of their model accord well with empirical evidence about how the brain works.

The researchers' work was sponsored, in part, by MIT's Center for Brains, Minds, and Machines, which is funded by the National Science Foundation.

<http://bit.ly/1NOMUOw>

**National Science Foundation Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	74,859,339	81,487,208	79,255,278	78,978,705	78,952,919
Constant dollars*	80,137,804	84,749,947	81,079,170	79,553,652	78,952,919



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**

(Shown in descending order of expenditures)

- Computer Science and Artificial Intelligence Laboratory
- Research Laboratory of Electronics
- Earth, Atmospheric and Planetary Sciences
- Biological Engineering
- McGovern Institute for Brain Research
- Kavli Institute for Astrophysics and Space Research
- Haystack Observatory
- Mathematics
- Chemistry
- Media Laboratory

In fall 2014, the National Science Foundation funded the primary appointments of graduate students with 287 research assistantships and 199 fellowships.

The National Science Foundation has awarded Faculty Early Career Development (CAREER) Awards to 160 current faculty and staff members.

Other Federal Agencies

Selected Projects

Fertilize the ocean, cool the planet?

Phytoplankton, the microalgae at the base of most oceanic food webs, photosynthesize in sunlight. Many phytoplankton species also release dimethyl sulfide (DMS) into the atmosphere, where it forms sulfate aerosols, which can directly reflect sunlight or increase cloud cover and reflectivity, resulting in a cooling effect. The ability of phytoplankton to draw planet-warming carbon dioxide from the atmosphere and produce aerosols that promote further cooling has made ocean fertilization an attractive geoengineering method to reduce global warming.

But undesirable climate impacts could result from a large-scale operation, which would significantly increase emissions of DMS. In a study published in *Nature's Scientific Reports*, senior research scientist Chien Wang and others, found that enhanced DMS emissions, while offsetting greenhouse gas-induced warming across most of the world, would induce changes in rainfall patterns that could adversely impact water resources and livelihoods in some regions.

The researchers hope their investigation will inspire further studies of more realistic ocean fertilization scenarios, and of the potential impacts on marine ecosystems as well as human livelihoods. Further research will be needed, they say, to fully evaluate the viability of ocean fertilization as a geoengineering method to offset greenhouse gas-induced warming.

The study was funded by the Singapore National Research Foundation through the Singapore-MIT Alliance for Research and Technology Center for Environmental Sensing and Modeling, and grants from the National Science Foundation, Department of Energy, and Environmental Protection Agency.

<http://bit.ly/1EUMfu0>

Can rain clean the atmosphere?

As a raindrop falls through the atmosphere, it can attract tens to hundreds of tiny aerosol particles to its surface before hitting the ground. The process by which droplets and aerosols attract is coagulation, a

natural phenomenon that can act to clear the air of pollutants like soot and organic particles.

Atmospheric chemists at MIT have determined just how effective rain is in cleaning the atmosphere. Given the altitude of a cloud, the size of its droplets, and the diameter and concentration of aerosols, the team can predict the likelihood that a raindrop will sweep a particle out of the atmosphere.

Dan Cziczo says the results published in the journal *Atmospheric Chemistry and Physics*, represent the most accurate values of coagulation to date. These values, he says, may be extrapolated to predict rain's potential to clear a range of particles in various environmental conditions.

The paper's co-authors are postdoc Karin Ardon-Dryer and former postdoc Yi-Wen Huang. This research was funded, in part, by the National Oceanic and Atmospheric Administration.

<http://bit.ly/1EmOgPh>

Measuring climate change action

Reducing global greenhouse gas emissions could have big benefits in the U.S., according to a report released by the U.S. Environmental Protection Agency (EPA), including thousands of avoided deaths from extreme heat, billions of dollars in saved infrastructure expenses, and prevented destruction of natural resources and ecosystems.

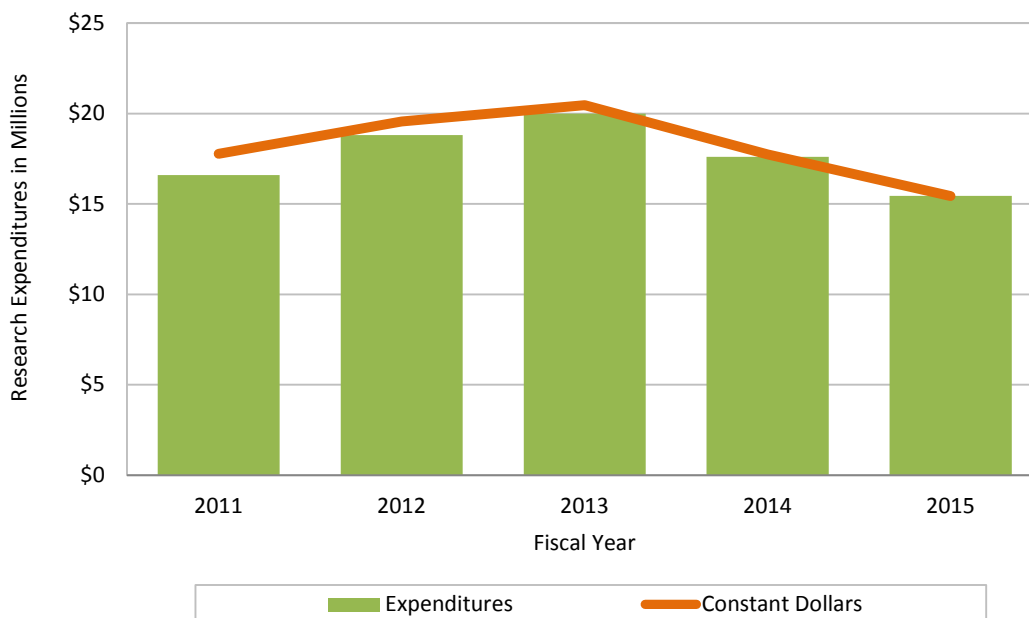
The report, "Climate Change in the United States: Benefits of Global Action", relies on research developed at the MIT Joint Program on the Science and Policy of Global Change to estimate the effects of climate change on 22 sectors in six areas: health, infrastructure, electricity, water resources, agriculture and forestry, and ecosystems.

The report is part of the ongoing Climate Impacts and Risk Analysis (CIRA) program, an EPA-led collaborative modeling effort among teams in the federal government, MIT, the Pacific Northwest National Laboratory, the National Renewable Energy Laboratory, and several consulting firms.

<http://bit.ly/1SHekaW>

**Other Federal Agencies Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	16,602,212	18,806,804	19,993,508	17,611,014	15,435,252
Constant dollars*	17,772,863	19,559,826	20,453,616	17,739,219	15,435,252



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

A few of the leading other federal agencies providing funding are: the Department of Commerce, the Department of Transportation, the Federal Aviation Administration, the Intelligence Advanced Research Projects Activity, and the Environmental Protection Agency.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**

(Shown in descending order of expenditures)

- Center for Transportation and Logistics
- Aeronautics and Astronautics
- Computer Science and Artificial Intelligence Laboratory
- Sea Grant College Program
- Civil and Environmental Engineering
- Urban Studies and Planning
- Mechanical Engineering
- Center for Global Change Science
- Materials Processing Center
- Sociotechnical Systems Research Center

In fall 2014, other federal agencies funded the primary appointments of graduate students with 50 research assistantships and 1 fellowship.

Nonprofit Organizations

Selected Projects

Physicists prove energy input predicts molecular behavior

The world within a cell is a chaotic space, where the quantity and movement of molecules and proteins are in constant flux. Trying to predict how a protein or process may fluctuate is essential to knowing how well a cell is performing. But such predictions are hard to pin down. Physicists at MIT have proved that at least one factor can set a limit on a given protein or process' fluctuations: energy. Given the amount of energy that a cell is spending, the fluctuations in a particular protein's quantity must be within a specific range; fluctuations outside this range would be deemed impossible, according to the laws of thermodynamics.

This idea also works in the opposite direction: Given a range of fluctuations in, say, the rate of a motor protein's rotation, the researchers can determine the minimum amount of energy that the cell must be expending to drive that rotation.

"This ends up being a very powerful, general statement about what is physically possible, or what is not physically possible, in a microscopic system," says Jeremy England. "It's also a generally applicable design constraint for the architecture of anything you want to make at the nanoscale."

Jeremy England and his colleagues, including Physics of Living Systems Fellow Todd Gingrich, postdoc Jordan Horowitz, and graduate student Nikolay Perunov, have published their results in *Physical Review Letters*. This research was supported in part by the Gordon and Betty Moore Foundation.

<http://bit.ly/1TKvDdN>

No more insulin injections?

In patients suffering from Type 1 diabetes, the immune system attacks the pancreas, eventually leaving patients without the ability to naturally control blood sugar. These patients must carefully monitor the amount of sugar in their blood, measuring it several times a day and then injecting themselves with insulin to keep their blood sugar levels within a healthy range.

A possible treatment would be to replace patients' destroyed pancreatic islet cells with healthy cells that could take over glucose monitoring and insulin release. The treatment has been used with one major drawback—the patients' immune systems attack the transplanted cells, requiring patients to take immunosuppressant drugs for the rest of their lives.

Now, a new advance from MIT, Boston Children's Hospital, and several other institutions may offer a way to fulfill the promise of islet cell transplantation. The researchers have designed a material that can be used to encapsulate human islet cells before transplanting them. In tests on mice, they showed that these encapsulated human cells could cure diabetes for up to six months, without provoking an immune response.

The work was supported, in part, by the JDRE, the Leona M. and Harry B. Helmsley Charitable Trust, the National Institutes of Health, and the Tayebati Family Foundation.

<http://bit.ly/23pRcUG>

In the world: Remote Mexican village uses solar power to purify water

Deep in the jungles of the Yucatan peninsula, residents of the remote Mexican village of La Mancalona are producing clean drinking water using the power of the sun. For nearly two years now, members of the community have operated and maintained the water purification system engineered by researchers at MIT.

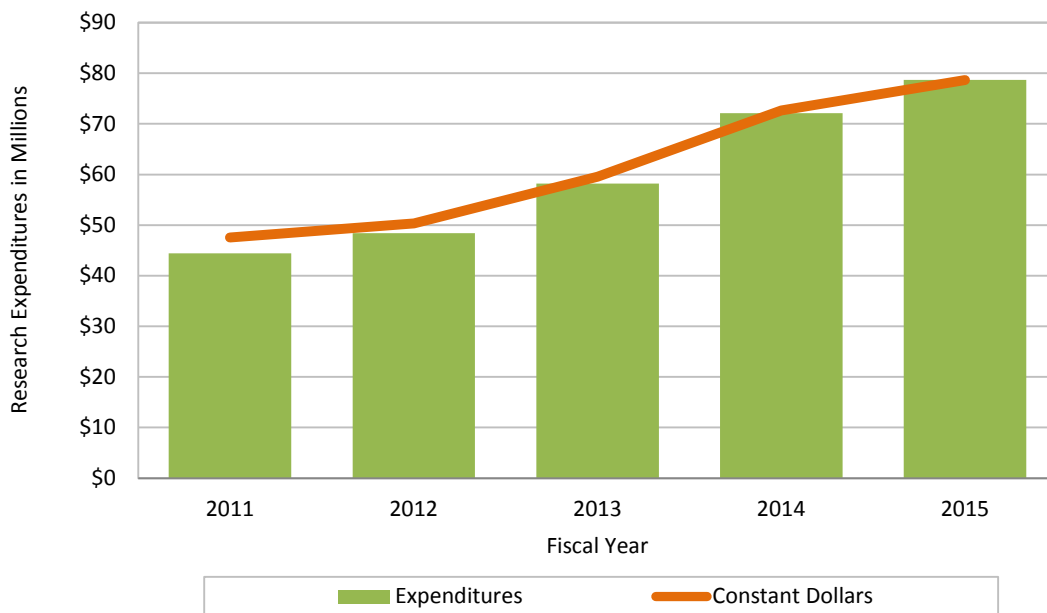
The system consists of two solar panels that convert sunlight into electricity; these, in turn, power a set of pumps that push water through semiporous membranes in a filtration process called reverse osmosis. The setup purifies both brackish well water and collected rainwater, producing about 1,000 liters of purified water a day for the 450 residents.

Now, in a study published in the journal *Desalination*, the MIT team reports that residents have successfully run the solar-powered system, having been trained by MIT researchers to operate and maintain the system. This work was supported, in part, by the W.K. Kellogg Foundation.

<http://bit.ly/1jOStmf>

**Nonprofit Organizations Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015**

	2011	2012	2013	2014	2015
Campus research	44,436,470	48,373,460	58,226,616	72,117,488	78,666,639
Constant dollars*	47,569,765	50,310,328	59,566,578	72,642,488	78,666,639



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2015**

(Shown in descending order of expenditures)

- Koch Institute for Integrative Cancer Research
- Masdar
- Computer Science and Artificial Intelligence Laboratory
- Economics
- Civil and Environmental Engineering
- Research Laboratory of Electronics
- Mechanical Engineering
- McGovern Institute for Brain Research
- Biological Engineering
- Materials Processing Center

Section 5

Lincoln Laboratory

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Lincoln Laboratory

MIT Lincoln Laboratory is a federally funded research and development center (FFRDC) operated by the Institute under contract with the Department of Defense (DoD). The Laboratory's core competencies are in sensors, information extraction (signal processing and embedded computing), communications, integrated sensing, and decision support, all supported by a strong program in advanced electronics technology.

Since its establishment in 1951, MIT Lincoln Laboratory's mission has been to apply technology to problems of national security. The Laboratory's technology development is focused on its primary mission areas—space control; air and missile defense technology; communication systems; cyber security and information sciences; intelligence, surveillance, and reconnaissance systems and technology; advanced technologies; tactical systems; and homeland protection. In addition, Lincoln Laboratory undertakes government-sponsored, nondefense projects in areas such as air traffic control and weather surveillance.

Two of the Laboratory's principal technical objectives are (1) the development of components and systems for experiments, engineering measurements, and tests under field operating conditions and (2) the dissemination of information to the government, academia, and industry. Program activities extend from fundamental investigations through the design process, and finally to field demonstrations of prototype systems. Emphasis is placed on transitioning systems and technology to industry.

MIT Lincoln Laboratory also emphasizes meeting the government's FFRDC goals of maintaining long-term competency, retaining high-quality staff, providing independent perspective on critical issues, sustaining strategic sponsor relationships, and developing technology for both long-term interests and short-term, high-priority needs.

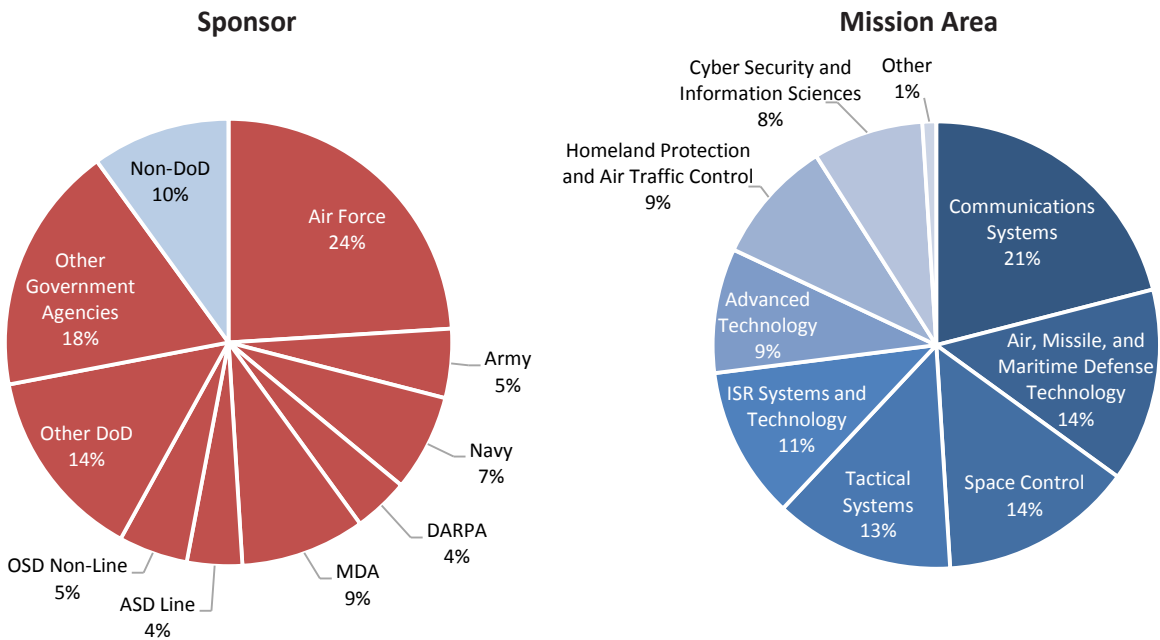
Over the past year, Lincoln Laboratory reached milestones in several areas:

- A prototype of a low-cost, multifunction phased array radar is expected to become the basis for upgrades to air traffic control and homeland protection radars across the country.
- Transitioned into operations the Multi-look Airborne Collector for Human Encampment and Terrain Extraction (MACHETE), a 3D ladar system designed to uncover hidden activity in heavily foliated areas. MACHETE has already been used in more than 160 sorties overseas.
- A new space-based sensing capability will better protect U.S. systems.
- Demonstrated the first flight of a large number of self-organizing unmanned aerial vehicles for new defense system protection needs.
- A novel adaptive antenna array antenna will give aircraft an enhanced communications capability in highly contested electromagnetic environments.
- Demonstrated the largest short-wave-infrared focal plane array capable of detecting individual photons. This array will be used in new airborne and space-based sensor applications.
- New techniques for secure and resilient cloud computing were developed and demonstrated.
- Exploited Laboratory's high-density, three-dimensional wafer-scale integration technology to develop novel circuits that convert electrical signals into optical signals for rapid data distribution.
- Three of Lincoln Laboratory's technologies were recognized with R&D 100 Awards, given by R&D Magazine to the year's 100 most innovative technologies. Lincoln Laboratory has received 26 R&D 100 Awards over the past six years.

Funding FY2015*

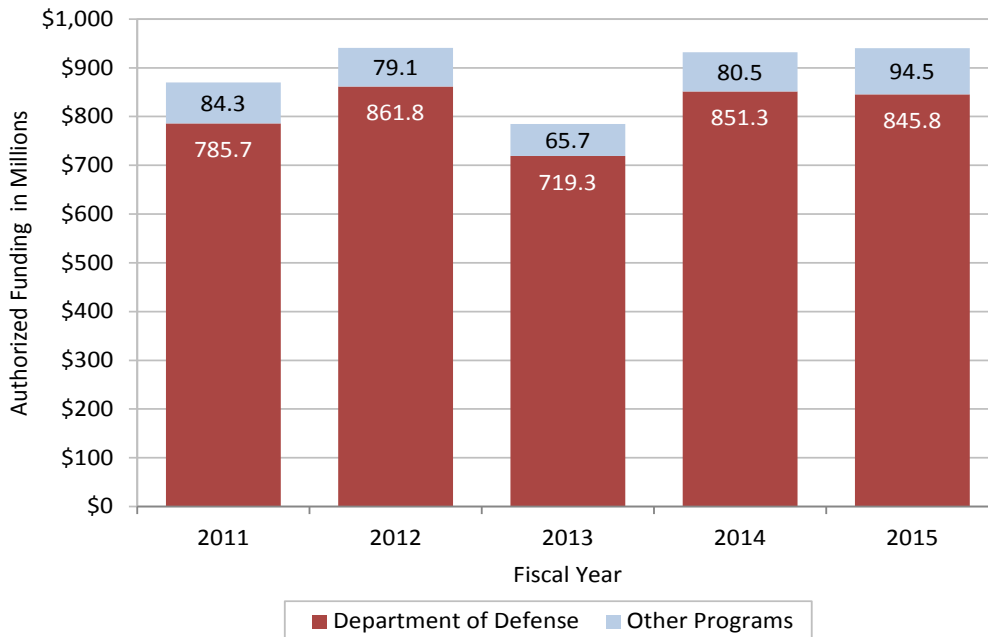
Total Funding = \$937.3 million

Breakdown of Laboratory Program Funding



DARPA: Defense Advanced Research Projects Agency
 ASD Line: Assistant Secretary of Defense
 OSD Non-Line: Office of the Secretary of Defense
 MDA: Missile Defense Agency
 DoD: Department of Defense

**Total Funding
Fiscal Years 2011–2015***



*Lincoln Laboratory fiscal year runs concurrent with the U.S. Government fiscal year, October 1–September 30.

Major Programs/Prototypes

Multi-look Airborne Collector for Human Encampment and Terrain Extraction

Capable of collecting unobscured 3D imagery from an altitude of 25 kft and at an incredible area coverage rate (400 km²/hr at 25 cm resolution), MACHETE (Multi-look Airborne Collector for Human Encampment and Terrain Extraction) can peek through openings in dense canopy to form detailed images of natural and man-made structures existing at and near the ground level, mapping out city-scale areas in minutes. For a heavily forested area with 90% canopy cover that is the size of Central Park, MACHETE can provide detailed images of every building, footbridge, and walkway below the canopy at 25 cm resolution in approximately five minutes.

The canopy can be digitally “defoliated” to reveal the structures underneath at any selected height above ground. Time-of-flight measurement is combined with pointing information of MACHETE’s gimbaled scanning system and the position of the airborne platform to produce a geolocated 3D point-cloud image. The imagery is color-coded to indicate differences in scene elevation, with color brightness indicating the intensity of the reflected light. Advanced onboard processing and analysis algorithms enable the classification of features of interest.

Real-time Open Systems Architecture for Reagan Test Site Sensor Systems

Lincoln Laboratory designed, developed, and implemented a new Real-time Open Systems Architecture (ROSA II) technology that is improving the efficacy of the radar and optical sensors at the Reagan Test Site on the Kwajalein Atoll in the Marshall Islands.

ROSA II extends the open concept to all sensor and control system software and offers a previously unachieved level of real-time data accessibility and system control, allowing for netcentric operation at the sensor and provides an ability to rapidly implement new software functions or to substitute existing functions from other systems built with ROSA II. It enables the interoperability of diverse hardware and software components, so systems are not constrained to only one operating platform or only system-specific components.

Major Technology Transfers

Advanced Technology

A world-leading superconducting microelectronic process was made available to industry performers.

Air Traffic Control

Lincoln Laboratory is supporting the transition of a prototype ground-based sense-and-avoid system to the U.S. Army. The system will undergo deployment to five Army Gray Eagle operational sites this year.

Future technology transfer will be supported on an annual basis. Decision support tools are being transferred into the Federal Aviation Administration's Traffic Flow Management System through 2020. These tools provide 0–2-hour forecasts of convective weather impact on terminal arrival routes and use wind, ceiling, and visibility forecasts and airport-specific operating procedures to aid in setting airport arrival rate targets.

Communication Systems

Lincoln Laboratory transferred a software implementation of the Dynamic Link Exchange Protocol to a group of three companies developing advanced communication systems. The protocol, which is undergoing standardization in the Internet Engineering Task Force, an international community of network researchers, will provide improved queuing and flow control for wireless networks.

An advanced algorithm for fast computation of wireless communications interference in radio networks was transitioned into two commercial wireless network simulation software frameworks. These frameworks are widely used in commercial and defense industry communications engineering to model wireless systems and to evaluate the performance of network and routing protocols.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

As part of its program for upgrading U.S. submarine sonars, Lincoln Laboratory transitioned adaptive beamforming, detection processing, and ranging algorithms, as well as improved collision warning indicators, to the Navy.

The Laboratory delivered to the Air Force Research Laboratory several advanced software capabilities to enhance processing, exploitation, and dissemination capabilities for Air Force Distributed Common Ground Systems.

Tactical Systems

The Laboratory has developed a tactical intelligence, surveillance, and reconnaissance sensor for small unmanned aerial vehicles (UAV). The sensor provides actionable information in real time, significantly improving the response time over currently fielded systems. The sensor has been integrated onto a tactical UAV platform in cooperation with industry partners, and hardened prototypes have been transitioned to the Army for operational use. Development is continuing to extend the payload for use on both moving and stationary platforms.

Lincoln Laboratory Mission Areas

Air and Missile Defense Technology

Lincoln Laboratory develops and assesses integrated systems for defense against ballistic missiles, cruise missiles, and air vehicles in tactical, regional, and homeland defense applications. Activities include the investigation of system architectures, development of advanced sensor and decision support technologies, development of flight-test hardware, extensive field measurements and data analysis, and the verification and assessment of deployed system capabilities. A strong emphasis is on rapidly prototyping sensor and system concepts and algorithms, and transferring resulting technologies to government contractors responsible for developing operational systems.

Communication Systems

Lincoln Laboratory is working to enhance and protect the capabilities of the Nation's global defense networks. Emphasis is placed on synthesizing communication system architectures, developing component technologies, building and demonstrating end-to-end system prototypes, and then transferring this technology to industry for deployment in operational systems. Current efforts focus on radio-frequency military satellite communications, free-space laser communications, tactical network radios, quantum systems, and spectrum operations.

Cyber Security and Information Sciences

Lincoln Laboratory conducts research, development, evaluation, and deployment of prototype components and systems designed to improve the security of computer networks, hosts, and applications. Efforts include cyber analysis; creation and demonstration of architectures that can operate through cyber attacks; development of prototypes that demonstrate the practicality and value of new techniques for cryptography, automated threat analysis, anti-tamper systems, malicious-code detection; and deployment of prototype technology to national-level exercises. Complementary advanced hardware, software, and algorithm technologies are developed

for processing large, high-dimensional datasets from a wide range of sources. In the human language technology area, emphasis is placed on realistic data and experimental evaluation of techniques for speech recognition, dialect identification, speech and audio signal enhancement, and machine translation.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

To expand intelligence, surveillance, and reconnaissance (ISR) capabilities, Lincoln Laboratory conducts research and development in advanced sensing, signal and image processing, automatic target classification, decision support systems, and high-performance computing. By leveraging these disciplines, the Laboratory produces novel ISR system concepts for both surface and undersea applications. Sensor technology for ISR includes passive and active electro-optical systems, surface surveillance radar, radio-frequency geolocation, and undersea acoustic surveillance. Increasingly, the work extends from sensors and sensor platforms to include the processing, exploitation, and dissemination technologies that transform sensor data into the information and situational awareness needed by operational users. Prototype ISR systems developed from successful concepts are then transitioned to industry and the user community.

Tactical Systems

Lincoln Laboratory assists the Department of Defense (DoD) in improving the development and employment of various tactical air and counterterrorism systems through a range of activities that include systems analysis to assess technology impact on operationally relevant scenarios, detailed and realistic instrumented tests, and rapid prototype development of U.S. and representative threat systems. A tight coupling between the Laboratory's efforts and DoD sponsors and warfighters ensures that these analyses and prototype systems are relevant and beneficial to the warfighter.

Space Control

Lincoln Laboratory develops technology that enables the Nation's space surveillance system to meet the challenges of space situational awareness. The Laboratory works with systems to detect, track, and identify man-made satellites; collects orbital-debris detection data to support space-flight safety; performs satellite mission and payload assessment; and investigates technology to improve monitoring of the space environment, including space weather and atmospheric and ionospheric effects. The technology's emphasis is the application of new components and algorithms to enable sensors with greatly enhanced capabilities and to support the development of netcentric processing systems for the Nation's Space Surveillance Network.

Advanced Technology

The Advanced Technology mission supports national security by identifying new phenomenology that can be exploited in novel system applications and by then developing revolutionary advances in subsystem and component technologies that enable key, new system capabilities. These goals are accomplished by a community of dedicated employees with deep technical expertise, collectively knowledgeable across a wide range of relevant disciplines and working in unique, world-class facilities. This highly multidisciplinary work leverages solid-state electronic and electro-optical technologies, innovative chemistry, materials science, advanced radio frequency technology, and quantum information science.

Homeland Protection

The Nation's security is supported by Lincoln Laboratory's innovative technology and architectures that help prevent terrorist attacks within the United States, reduce the vulnerability of the nation to terrorism, minimize the damage from terrorist attacks, and facilitate recovery from either man-made or natural disasters. The broad sponsorship for this mission area spans the DoD, the Department of Homeland Security, and other federal, state, and local entities. Recent efforts include architecture studies for the defense of civilians and facilities, new microfluidic technologies for DNA assembly and transformation and for gene synthesis, improvement of the Enhanced Regional Situation Awareness system for the National Capital Region, the assessment of

technologies for border and maritime security, and the development of architectures and systems for disaster response.

Aviation Research

Since 1971, Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development of new technology for air traffic control. This work initially focused on aircraft surveillance and weather sensing, collision avoidance, and air-ground data link communication. The program has evolved to include safety applications, decision support services, and air traffic management automation tools. The current program supports the FAA's Next Generation Air Transportation System (NextGen). Key activities include development of the next-generation airborne collision avoidance system; refinement and technology transfer of NextGen weather architectures, including cloud-processing and netcentric data distribution; and the development of standards and technology supporting unmanned aerial systems' integration into civil airspace.

Advanced Research Portfolio

Internal research and development at Lincoln Laboratory is supported through congressionally appropriated funding, known as the Line, administered by the Office of the Assistant Secretary of Defense for Research and Engineering. The Line is the Laboratory's primary source of relatively unconstrained funding and is used to fund the long-term strategic technology capabilities of established and emerging mission areas. Line projects form an Advanced Research portfolio focused on addressing technology gaps in critical problems facing national security.

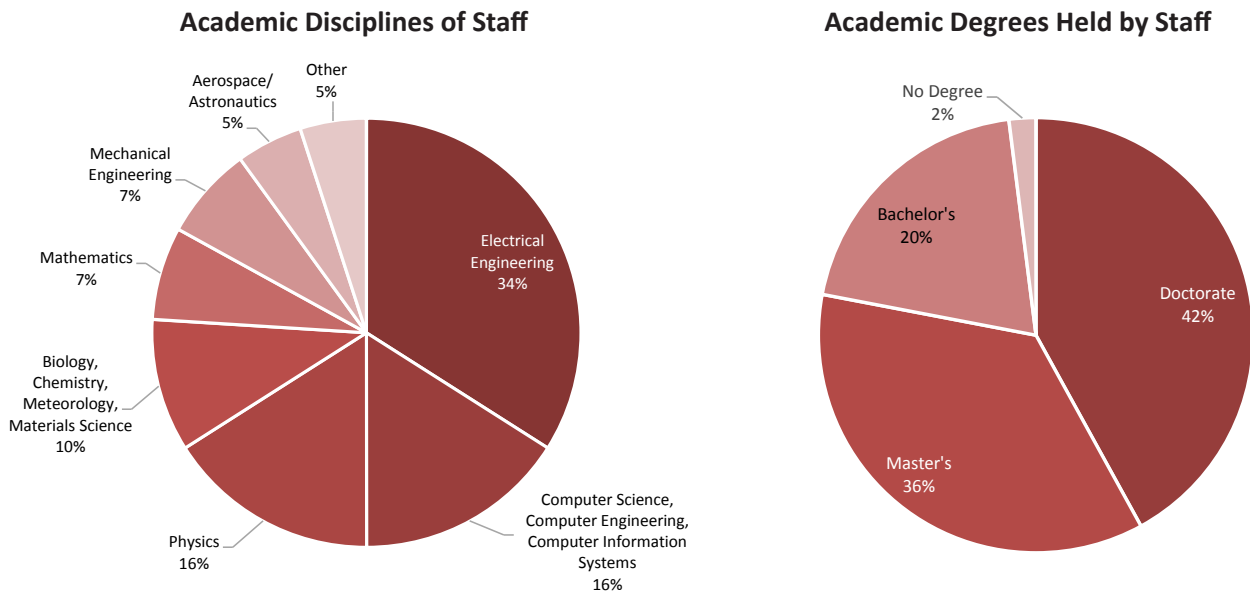
Projects supported by the Line are organized according to technology categories that are selected to address gaps in existing and envisioned mission areas. Nine technology categories were selected to include both core and emerging technology initiatives. Currently, five core-technology areas are in the Advanced Research Portfolio: advanced devices; optical systems and technology; information, computation and exploitation; RF systems and technology; and cyber security. In addition, there are four emerging-technology initiatives: novel and engineered materials; quantum system sciences; biomedical sciences; and autonomous systems.

Lincoln Laboratory Technical Staff

Lincoln Laboratory employs 1,740 technical staff, 433 technical support personnel, 1,055 support personnel, and 520 subcontractors. Three-quarters of the technical staff have advanced degrees, with 42% holding doctorates. Professional development opportunities and challenging cross-disciplinary projects are responsible for the Laboratory's ability to retain highly qualified, creative staff.

Lincoln Laboratory recruits at more than 60 of the Nation's top technical universities, with 65 to 75% of new hires coming directly from universities. Lincoln Laboratory augments its campus recruiting by developing long-term relationships with research faculty and promoting fellowship and summer internship programs.

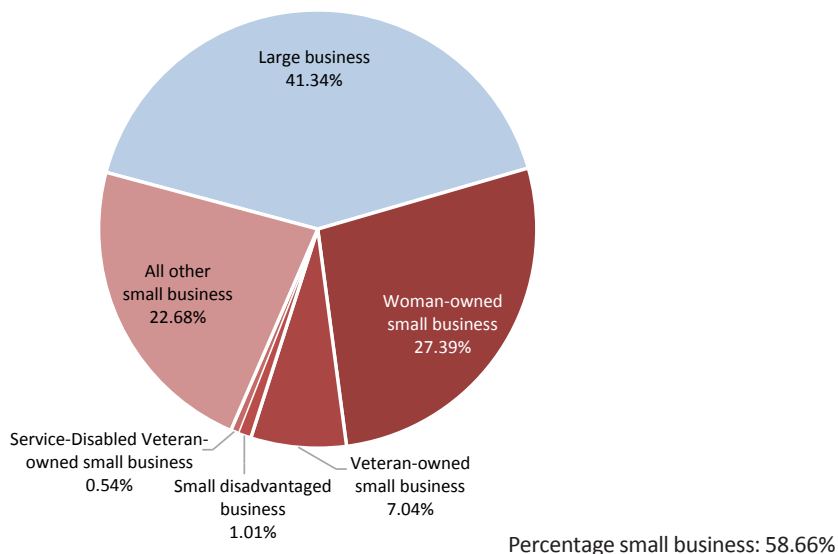
Composition of Professional Technical Staff



Lincoln Laboratory's Economic Impact

During fiscal year 2015, the Laboratory issued subcontracts with a value of approximately \$600 million. The Laboratory awarded subcontracts to businesses in all 50 states and purchased more than \$351 million in goods and services from New England companies in 2015, with Massachusetts businesses receiving approximately \$293 million. Economies in states as distant as California and Texas also realized significant benefits due to the Laboratory. More than 58% of Laboratory subcontracts were awarded to small businesses of all types in 2015.

Contract Award by Category of Business (FY2015)*



*As reported to the Defense Contract Management Agency (DCMA). Lincoln Laboratory fiscal year runs concurrent with the U.S. Government fiscal year, October 1–September 30.

MIT/Lincoln Laboratory Interactions

Lincoln Laboratory invests in developing and sharing the knowledge that will drive future technological advances and inform the next generation of engineers. Our educational collaborations with MIT are below.

Independent Activities Period at MIT

Lincoln Laboratory technical staff led activities offered during MIT's Independent Activity Period (IAP) in 2015. Lincoln Laboratory expanded the number of noncredit courses organized and led by its technical staff members to seven activities. Many of this year's IAP noncredit activities were held at Beaver Works.

VI-A Master of Engineering Thesis Program

Students in MIT's VI-A Master of Engineering Thesis Program spend two summers as paid interns at Lincoln Laboratory, contributing to projects related to their courses of study. Then, the students work as research assistants while developing their master of engineering theses under the supervision of both Laboratory engineers and MIT faculty. In 2015, five VI-A students participated in the program, gaining experience in testing, design, development, research, and programming.

Research Assistantships

Lincoln Laboratory employs a limited number of research assistants from MIT. Working with engineers and scientists for three to five years, these students contribute to sponsored programs while investigating the questions that evolve into their doctoral theses.

Undergraduate Research Opportunities and Practice Opportunities Programs

Lincoln Laboratory partners with MIT's Undergraduate Research Opportunities Program (UROP) and Undergraduate Practice Opportunities Program (UPOP). Program participants at the Laboratory develop research proposals, perform experiments, and analyze data. In 2015, twelve undergraduates were hired as UROP interns and seven as UPOP interns.

Advanced Concepts Committee

The Advanced Concepts Committee (ACC) provides funding and technical support for researchers who are investigating novel concepts that address high-priority national problems. The ACC encourages collaborative projects with MIT faculty and funds projects conducted by MIT researchers in areas pertinent to Laboratory programs.

Beaver Works

Beaver Works, a joint initiative between Lincoln Laboratory and the MIT School of Engineering, serves as an engine for innovative research and a mechanism for expanding project-based learning opportunities for students. By leveraging the expertise of MIT faculty, students and researchers, and Lincoln Laboratory staff, Beaver Works is strengthening research and educational partnerships to find solutions to pressing global problems.

The signature Beaver Works collaboration is the capstone course, an MIT engineering class at the center of which is a project to develop technology that solves a real-world problem identified by Lincoln Laboratory researchers. The fabrication areas offer access to tools and high-tech equipment, such as 3D printers and a laser cutter, that support construction of prototypes by students from the engineering department, the MIT Robotics Club, and the MIT UAV Club. MIT undergraduate and graduate students participated in the Assistive Technologies Hackathon (ATHack) at Beaver Works. Teams of students prototyped engineering solutions to problems faced by the disabled, such as a voice-activated cane and a hands-free walker.

Beaver Works extends project-based learning to local K–12 schoolchildren. In 2015, nine groups were involved in different science, technology, engineering, and mathematics (STEM) programs held at the center, including a build-a-radar workshop directed by instructors from the Lincoln Laboratory; weekly practices for the Lincoln Laboratory teams that participate in the national CyberPatriot computer-network security challenges; and an ongoing mentorship program with the Community Charter School of Cambridge.

Test Facilities and Field Sites

Hanscom Field Flight and Antenna Test Facility

The Laboratory operates the main hangar on the Hanscom Air Force Base flight line. This ~93,000-sq-ft building accommodates the Laboratory Flight Test Facility and a complex of state-of-the-art antenna test chambers. The Flight Facility houses several Lincoln Laboratory–operated aircraft used for rapid prototyping of airborne sensors and communications.



Hanscom Field Flight and Antenna Test Facility

Millstone Hill Field Site, Westford, MA

MIT operates radio astronomy and atmospheric research facilities at Millstone Hill, an MIT-owned, 1,100-acre research facility in Westford, Massachusetts. Lincoln Laboratory occupies a subset of the facilities whose primary activities involve tracking and identification of space objects.



Millstone Hill Field Site, Westford, Massachusetts

Reagan Test Site, Kwajalein, Marshall Islands

Lincoln Laboratory serves as the scientific advisor to the Reagan Test Site at the U.S. Army Kwajalein Atoll installation located about 2,500 miles WSW of Hawaii. Twenty staff members work at this site, serving two- to three-year tours of duty. The site's radars and optical and telemetry sensors support ballistic missile defense testing and space surveillance. The radar systems provide test facilities for radar technology development and for the development of ballistic missile defense techniques.



Reagan Test Site, Kwajalein, Marshall Islands

Other Sites

Pacific Missile Range Facility, Kauai, Hawaii
Experimental Test Site, Socorro, New Mexico

Lincoln Laboratory Outreach Metrics

Community outreach programs are an important component of the Laboratory’s mission. Outreach initiatives are inspired by employees’ desires to help people in need and to motivate student interest in science, technology, engineering, and mathematics (STEM). The Laboratory accommodates an increasing number of outreach programs each year.

Some of our most successful programs are listed below.

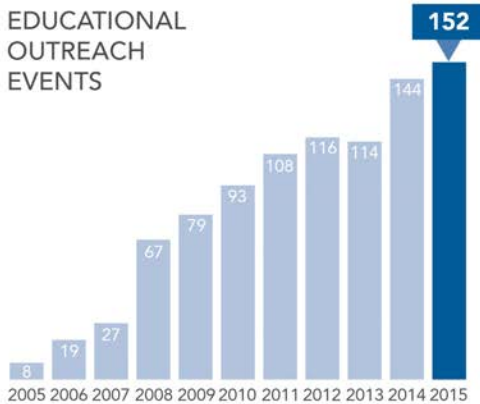
Lincoln Laboratory Outreach in 2015

32
EDUCATIONAL OUTREACH
STEM PROGRAMS
IN K-12

7 NEW EDUCATIONAL
OUTREACH PROGRAMS



6 OUTREACH
PROGRAMS
SHOW SIGNIFICANT
GROWTH



31
GIVING
PROGRAMS

3 NEW GIVING
PROGRAMS

LLRISE

Nine technical staff members taught various portions of the fourth Lincoln Laboratory Radar Introduction for Student Engineers (LLRISE) Workshop and helped high-school students build their own Doppler and range radars. The students were instructed in computer-aided design, 3D printing, circuit board assembly, electromagnetics, pulse compression, signal processing, antennas, MATLAB programming, electronics, and the principles of physics. Participants resided on the MIT campus, where they received advice on the college admissions process.

LLCipher

Lincoln Laboratory’s new one-week workshop, LLCi-pher provides an introduction for high-school students to modern cryptography—a math-based, theoretical approach to securing data. Lessons in abstract algebra, number theory, and complexity theory provide students with the foundational knowledge needed to understand theoretical cryptography.

CyberPatriot

Lincoln Laboratory sponsored three teams in CyberPatriot, a national competition for high-school students learning defensive computer security. The 14 students were mentored by Laboratory staff. After learning how to identify malware, “clean” a computer system, and establish a secure network, the teams competed in the statewide competition. One team advanced to the Northeast regional competition.

Wearables Workshop

Lincoln Laboratory’s Kristen Railey presented a full-day workshop to introduce high-school girls to engineering by having them make their own wearables—apparel and accessories that incorporate computer and electronic technologies. The girls left the workshop with 3D-printed bracelets but also with basic skills in computer-aided design (CAD), computer programming, and circuitry. The girls learned about the applications of 3D printers; attended a session on CAD software; and programmed light-emitting diodes for a shoe-wearable electronic circuit that they built.

Section 6

MIT and Industry

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MIT and Industry

Since its founding in 1861, MIT has fostered a problem-solving approach that encourages researchers to work together across departments, fields, and institutional boundaries. The resulting collaborations have included thousands of fruitful partnerships with industry.

- Industry sponsored R&D at MIT totaled \$134 million in FY2015.
- Over 700 companies provided R&D/gift support to MIT; 38 companies funded \$1 million+, 201 companies funded \$100 thousand–\$1 million.

Entrepreneurial Ecosystem

MIT also understands the fastest path from innovation to commercialization is often led by young, entrepreneurial start-up companies, and the Institute has taken great care to design and build a unique, highly effective entrepreneurial ecosystem. It brings the world's best and brightest into a culture of "Mens et Manus," i.e. "mind and hand" focused on discoveries of real, practical impact and strong commercial value.

MIT's vibrant entrepreneurial ecosystem benefits from its historical entrepreneurial culture, supported by specialized entrepreneurship programs and classes, student clubs, and networking across all MIT departments and schools and between MIT and the surrounding entrepreneurship and venture capital community. Formal MIT institutions like the Technology Licensing Office, Venture Mentoring Service, and the Deshpande Center for Technological Innovation are committed to the continued health and growth of the MIT entrepreneurial ecosystem.

The impact of MIT's entrepreneurial ecosystem was quantified by a 2011 Kauffman Foundation Entrepreneurship Study:

- 25,000+ companies have been founded by MIT alums creating 3.3+ million jobs and \$2 trillion in annual world sales.
- Five states gaining the most jobs from companies started by MIT alumni were Massachusetts, with just under 1 million jobs; California, with 526,000 jobs; New York, with 231,000 jobs; Texas, with 184,000 jobs; and Virginia, with 136,000 jobs.
- MIT acts as a magnet for foreign entrepreneurs. Half of those companies created by "imported" entrepreneurs, 2,340 firms, are headquartered in the United States, generating their principal revenue (\$16 billion) and employment (101,500 people) benefits here.

Partnering at MIT

Industry partners at MIT are global industry leaders who understand that technological advantage and innovation are key drivers to their competitive advantage. These are leaders who have created and defined industries, who quickly grasp the implications of breakthrough technology. Industry managers engage fully in MIT's collaborative, interdisciplinary culture, and join big thinkers who are perpetually focused on wringing practical applications from excellent ideas.

Strategic Partnerships

In 1994, MIT began to build new kinds of research partnerships, creating longer-term alliances with major corporations that would allow these companies to work with MIT to develop programs and strategies that address areas of rapid change. In return for their research and teaching support, the corporations share ownership of patentable inventions and improvements developed from the partnership. In a number of these alliances, funds are earmarked for specific education projects.

A selection of these partnerships are described below.

ExxonMobil

In 2014, ExxonMobil became a founding member of the MIT Energy Initiative (MITEI), a unique collaboration aimed at working together to advance and explore the future of energy. ExxonMobil has had a long and productive relationship with faculty and students at MIT, and in its most recent agreement collaborates on a wide range of projects, including research to improve and expand renewable energy sources and find more efficient ways to produce and use conventional hydrocarbon resources. The agreement also establishes 10 graduate energy fellowship appointments each year at MIT (ExxonMobil Energy Fellows). These fellowships will support operating costs and expenses for talented graduate students while they pursue their selected areas of study and research.

Novartis

Novartis and MIT have launched a long-term research collaboration aimed at transforming the way pharmaceuticals are produced. The partnership, known as the Novartis-MIT Center for Continuous Manufacturing, will work to develop new technologies that could replace the conventional batch-based system in the pharmaceuticals industry—which often includes many interruptions and work at separate sites—with continuous manufacturing processes from start to finish. The Novartis-MIT Center for Continuous Manufacturing combines the industrial expertise of Novartis with MIT’s leadership in scientific and technological innovation.

Philips

In May 2015, Philips announced an alliance with MIT that will ultimately support MIT research in the company’s core areas of health care and lighting solutions technology. The agreement follows the company’s recent decision to move its North American research headquarters to Kendall Square, citing the area’s concentration of startups and research labs—especially in the biomedical area—and for its proximity to MIT. Research projects under the alliance are expected to focus on areas such as lighting for green buildings and cities; clinical decision support; clinical informatics; interventional guidance, planning, and assessment; and medical ultrasound, photonics, and bioinformatics.

RIKEN

RIKEN is a nonprofit corporation with financial support furnished by the Japanese government and industry. It has funded research at MIT in learning and memory, neuroscience of higher order cognition, and plasticity of the developing and mature brain. Since its 1998 “Agreement for Collaboration in Neuroscience Research, the fruitful RIKEN collaboration has created the RIKEN-MIT Neuroscience Research Center, the RIKEN Brain Science Institute (BSI), and the RIKEN-MIT Center for Neural Circuit Genetics, directed by Nobel Laureate Susumu Tonegawa.

Samsung

Samsung chose MIT for its energy research focus and the decision to embark on this collaboration was made in parallel with the establishment of its Advanced Materials Lab in Cambridge. Current project topics include energy storage, all-inorganic quantum dot photovoltaics, computational materials design (materials genome), and functional layer-by-layer synthesis.

Tata

The MIT Tata Center for Technology + Design was founded in 2012 with generous support from the Tata Trusts. The Center’s research and education mission is to develop solutions to challenges facing resource-constrained communities globally, with an initial focus on India. Center-affiliated faculty and graduate student Tata Fellows engage in hands-on projects, with an approach that is rigorous and relevant to societal, economic, environmental, and political factors. The Tata Center brings together technical, pedagogical, and organizational expertise from across MIT to provide holistic support to more than 40 projects in the developing world, focused on agriculture, energy, environment, health, urbanization, and water. See page 103 for more information.

Selected Projects

The Future of Food

MITCityFARM, a Media Lab project led by Caleb Harper, employs a methodology that has the potential to reduce water consumption for agriculture by 98%, eliminate chemical fertilizers and pesticides, double nutrient densities and reduce embodied energy in produce by a factor of ten. Harper hopes to catalyze a paradigm shift from traditional practice to resource leveraged and environmentally optimized urban food growing solutions. MITCityFARM exploits innovative research and development of hydroponic, aquaponic and aeroponic production systems, novel environmental, diagnostic and networked sensing, control automation, autonomous delivery and harvest systems, data driven optimization and reductive energy design.

<http://bit.ly/1WViyAB>

Programming Materials for Better Design

MIT's Self-Assembly Lab, directed by Skylar Tibbits, is harnessing the power of computer sciences to program the physical world to assemble and transform itself, taking advantage of the transformational potential of precise material, geometric, and kinetic properties. On a recent project with Airbus, the lab developed a programmable carbon fiber flap to control airflow; the flap automatically opens and closes based on temperature, altitude or pressure as the plane leaves the ground and flies. Such an adaptable component could minimize weight, dispense with the need for a failure-prone electromechanical actuator, and avoid the need for pilots to control it.

<http://ilp.mit.edu/newsstory.jsp?id=20909>

Body on a Chip Helps Accelerate Drug Discovery

The BIO-MIMETICS program at MIT, led by Linda Griffith, is part of a cooperative agreement between MIT and DARPA, developed to create a versatile microfluidic platform that can incorporate up to 10 individual engineered human microphysiological organ system modules in an interacting circuit. The modules will be designed to mimic the functions of specific organ systems representing a broad spectrum of human tissues, including the circulatory,

endocrine, gastrointestinal, immune, integumentary, musculoskeletal, nervous, reproductive, respiratory and urinary systems. The goal of the program is to create a versatile platform capable of accurately predicting drug and vaccine efficacy, toxicity, and pharmacokinetics in preclinical testing.

<http://ilp.mit.edu/newsstory.jsp?id=19645>

Fiber Made by Transforming Materials

Chong Hou and researchers from fibers@MIT Group are practicing a kind of “alchemy,” turning inexpensive and abundant materials into high-value ones. Drawing thin fibers from bulk materials is nothing new, but the group discovered that when aluminum metal and silica glass are heated and drawn, they react chemically and produce a fiber with a core of pure, crystalline silicon—the raw material of computer chips and solar cells—and a coating of silica. It's the first time fibers created through this method can have a composition that's completely different than that of the starting materials. Yoel Fink, who leads fibers@MIT, says the technology could open new possibilities for electronics—including solar cells and microchips—to be incorporated into fibers and woven into clothing or accessories.

<http://bit.ly/1TTxMUn>

Raising the IQ of UAVs

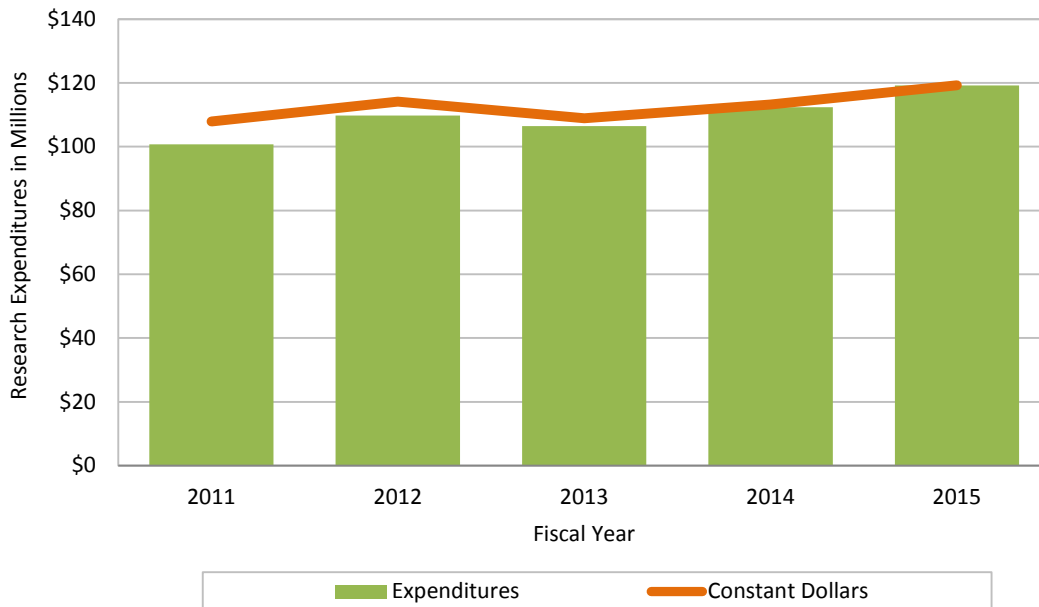
Before drone-delivered packages can become a reality, UAVs need to be taught to think for themselves. Nick Roy, former head of Google Inc.'s drone-delivery project, Project Wing, and now director of MIT's Robust Robotics Group, says that UAVs require more autonomy to avoid collisions and crashes, as well as to understand what's happening around them. Roy is studying the use of approximation algorithms to surmount computational challenges of fusing and integrating data from multiple sensors. Ultimately, the group hopes to develop sophisticated algorithms to enable UAVs to take instructions from people or collaborate with them.

<http://ilp.mit.edu/newsstory.jsp?id=21067>

Campus Research Sponsored by Industry

Industry Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015

	2011	2012	2013	2014	2015
Campus research	100,762,512	109,744,829	106,447,700	112,379,455	119,238,077
Constant dollars*	107,867,456	114,138,999	108,897,368	113,197,553	119,238,077



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2015 (shown in descending order of expenditures)

MIT Energy Initiative
 Chemical Engineering
 Mechanical Engineering
 Computer Science and Artificial
 Intelligence Laboratory
 Koch Institute for Integrative Cancer Research
 Media Laboratory
 School of Management
 Center for Transportation and Logistics
 Chemistry
 Aeronautics and Astronautics

MIT is a leader in conducting research sponsored by industry. Over 200 industrial sponsors supported research projects on the MIT campus in FY2015, with over \$119 million in expenditures. Companies often join together in these collaborations to support multi-disciplinary research programs in a wide range of fields.

Managing the Industry/ University Interface

Drawing on decades of successful industry collaboration, MIT has assembled a coordinated team of professionals who expertly manage the important industry/university interface, leveraging and exploiting proven pathways for two-way knowledge transfer.

Industrial Liaison Program

Officers at MIT's Industrial Liaison Program (ILP) help company managers by scheduling and facilitating face-to-face meetings with MIT faculty, coordinating on-campus networking activities, and advising company managers on how to navigate, adapt and benefit from the dynamic, interdisciplinary MIT environment. Two hundred of the world's leading companies partner with the Industrial Liaison Program to advance their research agendas at MIT, and ILP member companies account for approximately 44% of all single-sponsored research expenditures and corporate gifts/grants at MIT (FY2014).

Office of Corporate Relations

MIT's Office of Corporate Relations (OCR), the organizational parent of the ILP, aids and directs companies interested in pursuing significant, multi-year, multi-disciplinary involvement with the Institute. OCR works with MIT senior administration, faculty, and company executives to structure and define individualized alliances that mutually benefit the company and MIT. The result is a holistic industry/university relationship that addresses broad needs and interests, from specific research projects and initiatives, to executive education, technology licensing, and recruitment.

Office of Sponsored Programs

The Office of Sponsored Programs' mission is to conduct the centrally organized administrative, business, and financial functions related to award administration and to assist faculty, principal investigators, and their administrators in the identification of resources for and the management of individual sponsored projects consistent both with MIT's academic and research policies and with the stewardship requirements of and obligations to external sponsors.

Technology Licensing Office

The MIT Technology Licensing Office (TLO) is a world class model of excellence in university technology licensing. Its staff is especially attuned to the needs of pre-competitive research and promotes an Intellectual Property protocol that accelerates commercialization, and, at the same time, honors MIT's obligations to education and research. The TLO oversees a vibrant flow patenting/licensing activity

Technology Licensing Office Statistics for FY2015

Total number of invention disclosures:	795
Number of U.S. new utility patent applications filed:	293
Number of U.S. patents issued:	314
Number of licenses granted (not including trademarks and end-use software):	91
Number of options granted (not including options as part of research agreements):	33
Number of software end-use licenses granted:	33
Number of companies started (number of new license or option agreement to MIT technologies that serve as the foundation for a start-up company):	28

Entrepreneurship

MIT is recognized as one of the most entrepreneurial universities in the world. Its faculty ranks include hundreds of serial startup founders, and its hands-on approach to education encourages students to make a difference in the world by discovering and exploiting new technologies. The science-based ventures coming out of MIT helped transform Kendall Square into a major hub of biotech innovation, and the area thrives today with startups representing an array of industries from energy, to healthcare, to nanotech to advanced manufacturing.

\$100K Entrepreneurship Competition

The MIT \$100K Entrepreneurship Competition (student group) is the leading business plan competition in the world. The competition was founded in 1990 to encourage students and researchers in the MIT community to act on their talent, ideas, and energy to produce tomorrow's leading firms. Entirely student-managed, the competition has produced hundreds of successful ventures that have created value and employment.

Deshpande Center for Technological Innovation

The Deshpande Center for Technological Innovation was established at the MIT School of Engineering in 2002 to increase the impact of MIT technologies in the marketplace, and support a wide range of emerging technologies including biotechnology, biomedical devices, information technology, new materials, tiny tech, and energy innovations. Since 2002, the Deshpande Center has funded more than 80 projects with over \$9 million in grants. Eighteen projects have spun out of the center into commercial ventures, having collectively raised over \$140 million in outside financing. Thirteen venture capital firms have invested in these ventures.

Martin Trust Center for MIT Entrepreneurship

The Martin Trust Center for MIT Entrepreneurship is committed to fostering and developing MIT's entrepreneurial activities and interests in three primary areas: education and research, alliance, and community. The Center educates and nurtures students from across the Institute who are interested in learning the skills to design, launch, and grow innovation-based ventures. The Center facilitates business and technology partnerships by combining breakthrough academic research with practical, proven experience. The people of the Center cultivate and nourish a thriving network that unifies academic, government, and industry leaders around the vision of entrepreneurial success.

MIT Startup Exchange

MIT Startup Exchange (STEX) connects industry to startups from across the MIT innovation ecosystem, fostering interactions that lead to strong partnerships. ILP members can engage the STEX community including 1000 active MIT-connected startup companies at all stages of development and representing seven technology clusters: ICT, Biotech, Nanotech, Energy Tech, Advanced Manufacturing, Healthcare, and Hybrid Innovation. STEX runs monthly workshops on topics in technology and innovation including robotics, mobility, biotech, energy, food, and cybersecurity. MIT STEX is a service of MIT's Industrial Liaison Program (ILP).

Venture Mentoring Service

Venture Mentoring Service (VMS) supports innovation and entrepreneurial activity throughout the MIT community by matching both prospective and experienced entrepreneurs with skilled volunteer mentors. VMS uses a team mentoring approach with groups of 3 to 4 mentors sitting with the entrepreneur(s) in sessions that provide practical, day-to-day professional advice and coaching. VMS mentors are selected for their experience in areas relevant to the needs of new entrepreneurs and for their enthusiasm for the program. VMS assistance is given across a broad range of business activity, including product development, marketing, intellectual property law, finance, human resources, and founders issues. VMS services are offered without charge to MIT students, alumni, faculty and staff in the Boston area.

Learning

Sloan Executive Education

MIT Sloan Executive Education programs are designed for senior executives and high-potential managers from around the world. From intensive two-day courses focused on a particular area of interest, to executive certificates covering a range of management topics, to custom engagements addressing the specific business challenges of a particular organization, their portfolio of non-degree, executive education and management programs provides business professionals with a targeted and flexible means to advance their career development goals and position their organizations for future growth.

Professional Education

MIT Professional Education provides short courses, semester or longer learning programs and customized corporate programs for science and engineering professionals at all levels. Taught by renowned faculty from across the Institute, MIT Professional Education programs offer professionals the opportunity to gain crucial knowledge in specialized fields to advance their careers, help their companies, and have an impact on the world.

- **Short Programs**—Over 40 courses, in two-to-five day sessions, are taught on the MIT campus each summer by MIT faculty/researchers and experts from industry and academia. Participants earn Continuing Education Units (CEUs) and a certificate of completion.
- **Advanced Study Program**—Enroll at MIT for a 16-week, non-matriculating, non-degree program that enables professionals to take regular MIT courses to gain the knowledge and skills needed to advance their careers and take innovative ideas back to their employers. Participants earn grades, MIT credit, and an Advanced Study Program certificate.
- **Custom Programs**—Enhance your organization's capabilities and expertise through customized programs tailored to meet your specific needs and priorities. These programs can be a single week or several weeks over a year with interrelated projects. These specialized courses can be delivered at MIT, the company site, or off site.

Leaders for Global Operations

The Leaders for Global Operations (LGO) program is an educational and research partnership among global operations companies and MIT's School of Engineering and Sloan School of Management. Its objective is to discover, codify, teach, and otherwise disseminate guiding principles for world-class manufacturing and operations. The 24-month LGO program combines graduate education in engineering and management for those with two or more years of full-time work experience who aspire to leadership positions in manufacturing or operations companies. A required six-month internship comprising a research project at one of LGO's partner companies leads to a dual-degree thesis, culminating in two master's degrees—an MBA (or SM in management) and an SM in engineering.

MIT Sloan Fellows Program in Innovation and Global Leadership

This full-time, 12-month (June–June) immersive MBA program is designed for high-performing mid-career professionals. The program typically enrolls more than 100 outstanding individuals with 10–20 years of professional experience from at least two dozen nations, representing a wide variety of for-profit and nonprofit industries, organizations, and functional areas. Many participants are sponsored by or have the strong support of their employers, but the program also admits independent participants, many with unique entrepreneurial experiences and perspectives. The program is characterized by a rigorous academic curriculum, frequent interactions with international business and government leaders, and a valuable exchange of global perspectives.

System Design and Management

System Design & Management (SDM) is the MIT master's program in engineering and management. Jointly offered by MIT's School of Engineering and the Sloan School of Management, SDM educates mid-career professionals to lead effectively and creatively by using systems thinking to solve large-scale, complex challenges in product design, development, and innovation.

Recruiting

Global Education and Career Development

The MIT Global Education and Career Development center assists employers in coordinating successful on- and off-campus recruitment of MIT students and provides students with opportunities to interact and network with professionals and obtain quality internships and full-time positions. MIT is proud to serve the needs of undergraduates (including Sloan), graduates and MIT alumni. (Departments that conduct their own recruiting include Chemistry, Chemical Engineering, and Sloan School of Management).

Sloan's Career Development Office

Sloan's Career Development Office (CDO) serves a vital role in connecting MIT Sloan's innovative master's students and alumni with the world's leading firms. The CDO is dedicated to supporting employer recruiting goals and helping them identify the best candidates for their organization.

Section 7

Global Engagement

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Global Engagement

MIT's problem-solving ambitions are global, and we cannot solve the most important world problems alone. Our wide-ranging international collaborations allow us access to outstanding students and colleagues, and provide our students with hands-on preparation for worldwide careers. Just as important, our global engagements lead us to important research problems and to fresh ways of thinking. While we are eager to share what we know, we go out into the world to learn.

President L. Rafael Reif

MIT strives to encourage the free flow of people and ideas by engaging in international research collaborations, providing international study and research opportunities for its students, and hosting international students and scholars. The following are some of MIT's many international research collaborations.

Singapore

Singapore University of Technology and Design

In 2010, MIT and the Singapore University of Technology and Design (SUTD) officially began a partnership that includes both education and research components. Under the education component, MIT will share its expertise with SUTD in a broad range of areas, including pedagogy, curriculum development, and faculty recruitment and development. MIT will also assist in designing programs to encourage innovation and entrepreneurship. By March 31, 2015, MIT completed the delivery of 93 courses to SUTD, six more than promised in the collaboration agreement. Additionally, by end of the Spring 2015 semester, MIT faculty will have participated in 43 two-week and 22 four-week co-teaching residencies, which means that MIT is well on the way of fulfilling the required 80 short-term residencies called for in the agreement. The fourth incoming class at SUTD matriculated in May of 2015, and the first class will graduate at the end of August 2015, a milestone for this fledgling university. In recent years, student exchanges have taken center stage in the collaboration as the third group of Singapore students arrived in this past June for their ten-week Global Leadership Program, and the fourth group of MISTI-Singapore students arrived at SUTD this June to assist in leadership training. In January 2015,

a new Winter IAP program was initiated in which 40 SUTD students participated in a three-week program focused on cross-cultural collaboration. As part of the program, the students could choose from 23 new and updated IAP courses developed from MIT-SUTD collaboration funding. A key feature of the research component is the SUTD-MIT International Design Centre (IDC). The IDC is a joint research project with facilities at both universities. The IDC aims to become the world's premier scholarly hub for technologically intensive design and serve as a nucleus for the growth of the MIT-SUTD Collaboration.

<http://sutd.mit.edu/>

Singapore-MIT Alliance for Research and Technology Centre

The Singapore-MIT Alliance for Research and Technology (SMART) Centre is a research enterprise established by MIT in partnership with the National Research Foundation of Singapore. The SMART Centre serves as an intellectual hub for research interactions between MIT and Singapore at the frontiers of science and technology. This partnership allows faculty, researchers, graduate students, and undergraduate students from MIT to collaborate with their counterparts from universities, polytechnics, research institutes, and industry in Singapore and throughout Asia. The SMART Centre is MIT's first research centre outside of Cambridge, Massachusetts, and its largest international research endeavor. See page 107 for information on Singapore-MIT Undergraduate Research Fellowships.

<http://smart.mit.edu/>

Russia

MIT Skoltech Initiative

In 2011, MIT and Russia initiated a multi-year collaboration to help conceive and launch the Skolkovo Institute of Science and Technology (Skoltech), a new graduate research university in Moscow, focused on a small number of pressing global issues and designed to stimulate the development of a robust innovation ecosystem in Russia. MIT serves as a key collaborator and advisor on programs, structures, policies, and operations in three key domains: research, education, and innovation/entrepreneurship. MIT has helped

establish the main elements of Skoltech's educational programs, including a PhD program and Master of Science programs in IT, Energy, Space, Design and Manufacturing, and Biomedicine. MIT has helped design and implement a student recruitment strategy and admissions process, and as of Spring 2015 has hosted approximately 75% of all Skoltech Master's students in Cambridge—for one month to multiple semesters. Part of Skoltech's effort to address specific real-world problems, which are also of high priority to the Russian Federation, is the establishment of a network of globally distributed Centers for Research, Education, and Innovation (CREIs). MIT designed and implemented a multi-stage submission and international peer-review process, and launched new MIT-led CREIs in Biomedicine (RNA Therapeutics and Infectious Diseases), Electrochemical Energy Storage, and in negotiations Energy Systems. Promoting innovation and entrepreneurship is central to Skoltech's mission. Toward that end, MIT has helped develop an entrepreneurship and innovation curriculum designed to provide foundational understanding in an action-based learning environment for Skoltech students, and has helped build the administrative and operational foundations for knowledge transfer and commercialization of emerging technologies.

<http://web.mit.edu/sktech/>

India

Tata Center for Technology and Design

The Tata Center for Technology and Design at MIT applies deep technical knowledge to the challenges of the developing world, particularly India, and provides holistic technical, educational, and financial support to MIT faculty and graduate students who are engaged with these challenges. Founded in 2012, the Center's work is made possible by a donation from the Tata Trusts, one of India's oldest philanthropic organizations.

The students, known as Tata Fellows, develop thesis projects that respond to large-scale opportunities to improve the lives of people in the lower strata of Indian society. These projects are chosen and developed with an emphasis on practicality, impact, and scalability within six overlapping focus areas: agriculture, energy, environment, health, urbanization, and water. The Center is currently supporting 59 Tata Fellows who are

enrolled in Master's and PhD programs across the Institute. So far, five new classes have been established at MIT with Center funding, with more planned for next year, and over 100 members of the MIT community, including Fellows, faculty and staff spend time in India advancing their projects each year.

<http://tatacenter.mit.edu/>

China

China Leaders for Global Operations

The China Leaders for Global Operations (CLGO) program was started in 2005 as a collaboration of MIT and the Shanghai Jiao Tong University (SJTU). The program was launched at the request of LGO industry partners to strengthen LGO global content for faculty and students, help partner companies' operations in China, and promote global manufacturing. CLGO offers China's only dual-degree, graduate-level academic program. The CLGO program is jointly offered by SJTU's two engineering schools, the SJTU Antai College of Economics and Management, and a dedicated group of CLGO industry partners. Graduates of the CLGO program receive the MBA degree from Antai, an S. M. degree from one of two SJTU engineering schools, and a certificate from the MIT LGO program. MIT supports the China LGO program by hosting SJTU faculty (32 to date) at MIT for extensive mentoring in courses that they in turn lead for the CLGO program, and by providing the all-English language CLGO curriculum. In addition, a review committee of MIT faculty makes periodic visits to meet CLGO stakeholders and assess the program's quality. MIT LGO and China LGO students collaborate each year through visits to Shanghai and Cambridge, including joint plant tours of partner company sites.

MIT China Educational Technology Initiative

The MIT-China Educational Technology Initiative (CETI) is MISTI-China's educational technology internship program. Since 1997, MIT-CETI has trained small teams of MIT students to work with numerous universities and high schools in China, building cross-cultural understanding between Chinese and American students through the application of technology. Approximately 20 MIT students participate in CETI each year in full summer and longer internships. CETI has established educational technology

programs with Chinese universities through partnerships with MIT OpenCourseWare (OCW) and MIT-iCampus. CETI university partners include Dalian University of Technology, Huazhong University of Science and Technology (Wuhan), Fuzhou University, Xi'an Jiaotong University, Yunlin University (Shaanxi Province), Qinghai University, Sichuan University, Kunming University of Science and Technology, Institute of Vocational Engineering (Hong Kong), and YuanZe University (Taiwan). In recent years, CETI has also held several educational technology summer camps at Tsinghua & Zhejiang universities in the departments of information technology. Additionally, in summer 2014, CETI has started collaborating with Google and MIT App Inventor organizing mobile phone applications workshops at Tianjin University, Shanghai World Foreign Languages Middle School, Shenzhen Institute of Information Technology, South China University of Technology, Lanzhou University, and Gansu Radio & Television University. And starting fall 2015, MIT-CETI will start collaborations with the MIT Samuel Tak Lee Real Estate Entrepreneurship Lab to send CETI teams to Chinese universities to introduce socially responsible entrepreneurship practices in areas of urban planning and real estate.

Middle East

Center for Clean Water and Clean Energy at MIT and KFUPM

Technologies related to the production of fresh water and low-carbon energy are the focus of a research and educational partnership between faculty in MIT's Department of Mechanical Engineering and King Fahd University of Petroleum and Minerals (KFUPM) in Dhahran, Saudi Arabia. The joint program operates through the Center for Clean Water and Clean Energy, and it includes projects on topics such as desalination, solar energy, nanoengineered membranes, leak detection, and advanced manufacturing. The eight-year collaboration includes more than a dozen large-scale collaborative research projects and a number of education and curriculum development projects. Approximately 25 MIT faculty are involved, with a similar number at KFUPM, and an overall head count (including graduate students and postdocs) of more than 150 people between the two schools. KFUPM faculty and graduate students have the opportunity to spend one or two semesters at MIT, and MIT

faculty visit KFUPM for one to two weeks each year. The Center also includes a unique outreach program that brings Saudi women engineers and scientists to MIT for research with our faculty. The Center is directed by Professor John H. Lienhard V and co-directed by Professor Kamal Youcef-Toumi.

CSAIL-Qatar Computing Research Institute

The CSAIL-Qatar Computing Research Institute (QCRI) research collaboration is a medium for knowledge joint-creation, transfer, and exchange of expertise between MIT-CSAIL and QCRI scientists. Scientists from both organizations are undertaking a variety of core computer science research projects—database management, Arabic language technology, new paradigms for social computing, and data visualization, etc.—with the goal of developing innovative solutions that can have a broad and meaningful impact. The agreement also offers CSAIL researchers and students exposure to the unique challenges in the Gulf region. Scientists at QCRI are benefiting from the expertise of MIT's eminent faculty and researchers through joint research projects that will enable QCRI to realize its vision to become a premier center of computing research regionally and internationally.

Kuwait-MIT Center for Natural Resources and the Environment

Established at MIT, in the year 2005, the Kuwait-MIT Center for Natural Resources and the Environment (CNRE) brings together faculty, students, and scientists to improve scientific and technical understanding of issues of natural resources, the environment, and related challenges.

The mission of the Center is to foster collaborations in research and education in the areas of Energy, Water and the Environment between MIT and institutions in Kuwait. CNRE sponsors a number of programs including grants to support collaborative research, and visitor exchange programs for Visiting Students, Visiting Scientists, and Postdoctoral Fellows.

The Center is funded by the Kuwait Foundation for the Advancement of Sciences (KFAS). Its leadership team consists of Associate Director: Prof. Jacopo Buongiorno of NSE; and Executive Director: Dr. Murad Abu-Khalaf.

<http://cnre.mit.edu/>

MIT and Masdar Institute Cooperative Program

In 2006, MIT began collaborating with the government of Abu Dhabi to establish a graduate research university focused on alternative energy, sustainability, and advanced technology. Since then Masdar Institute has grown to over 93 outstanding faculty and over 500 graduate students. MIT and Masdar Institute have collaborated on 70 research projects to date and the Cooperative Program continues to support Abu Dhabi's goal of developing human capital for a diversified knowledge-based economy. By ensuring high-quality, graduate education and advanced research, Masdar Institute prepares a high-caliber workforce to keep pace with ever-increasing technological changes and a growing research and development culture. The Cooperative Program offers MIT and Masdar Institute faculty and students access to new talent, ideas, and rich research and educational collaborations.

<http://web.mit.edu/mit-mi-cp/>

Portugal

MIT Portugal Program

The MIT Portugal Program was launched in October 2006 by the Portuguese Ministry of Science, Technology, and Higher Education as a large-scale international collaboration connecting MIT to government, academia, and industry in Portugal. The aim of the program is to transform the Portuguese economy by developing globally competitive higher education and research programs and synergies in: bioengineering systems, sustainable energy and transportation systems, and engineering design and advanced manufacturing. These academic-research initiatives are complemented by an array of ecosystem-building activities, including innovation and leadership training and venture activities. The partnership has recently been extended (2013–2017), underscoring its importance and impact for the Portuguese government and the value MIT brings to the country.

Other Global Initiatives

Global Supply Chain and Logistics Excellence (SCALE) Network

The MIT Center for Transportation and Logistics (MIT CTL) created the MIT Global Supply Chain and Logistics Excellence (SCALE) Network in 2003 as an international alliance of leading research and education centers dedicated to the development and dissemination of supply chain and logistics innovation. This international network spans four continents with Centers in North America (MIT CTL), Europe (Zaragoza, Spain), South America (Bogota, Colombia), and Asia (Kuala Lumpur, Malaysia). Each SCALE Center fosters relationships between its local students, faculty, and businesses as well as those across the network. More than 200 graduate students are enrolled annually in the various SCALE supply chain educational programs; many of which include a three week student and faculty exchange at MIT. The SCALE Network also features partnerships with over a hundred global corporations, such as Procter & Gamble, UPS, BASF, and Wal-Mart, that sponsor research, participate in events, and recruit students. Research projects recently undertaken by the SCALE network include projects on decision making under uncertainty, supply chain resilience, humanitarian logistics, sustainable supply chains, and global transportation reliability

Center for Advanced Urbanism

The overall goal of the MIT Center for Advanced Urbanism (CAU) is to establish a new theoretical and applied research platform to transform the quality of urban life. The Center is committed to achieving this goal via collaborative interdisciplinary research projects, intellectual discourse, leadership forums and conferences, publications, education of a new generation of leaders in the field, and a distinctive, highly influential presence at international gatherings focused on urbanism.

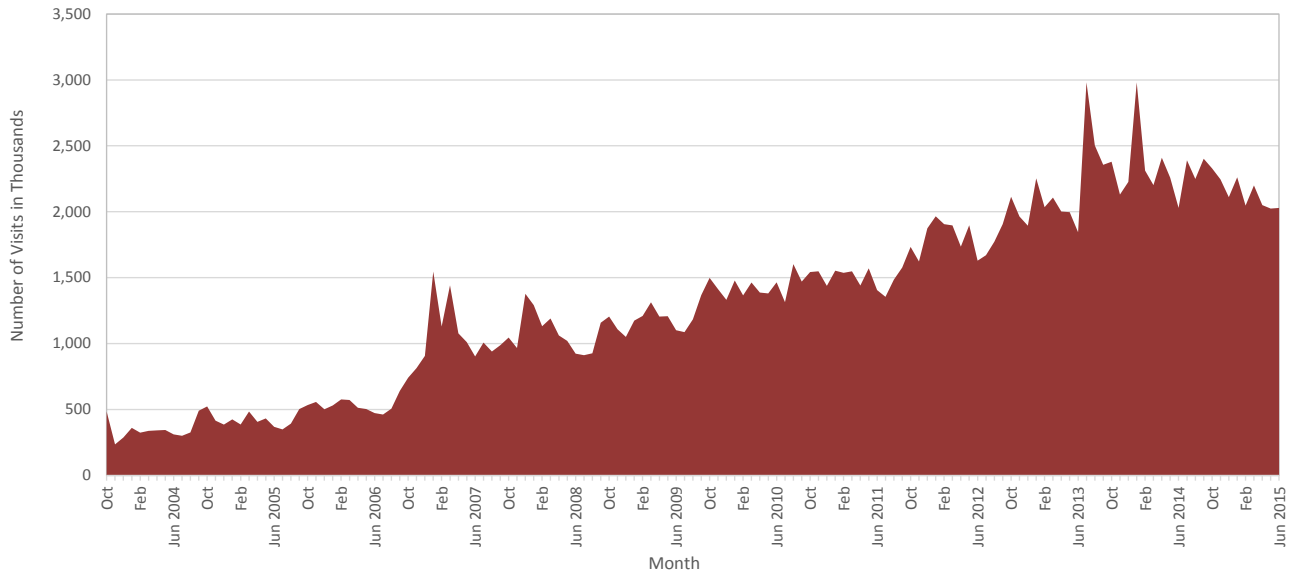
<http://cau.mit.edu/>

Digital Learning

OpenCourseWare and MITx represent MIT's largest and most far-reaching international outreach programs. With more than 2200 courses on OCW, many of them available in other languages through OCW translation affiliates in other countries, there

is something of interest for almost everyone. Since 2003, more than 200 million individuals have accessed MIT academic content through these programs, sometimes with astonishing results. Please see <http://ocw.mit.edu/about/ocw-stories/> for inspiring examples.

Monthly Visits to OCW Website (October 2003–June 2015)

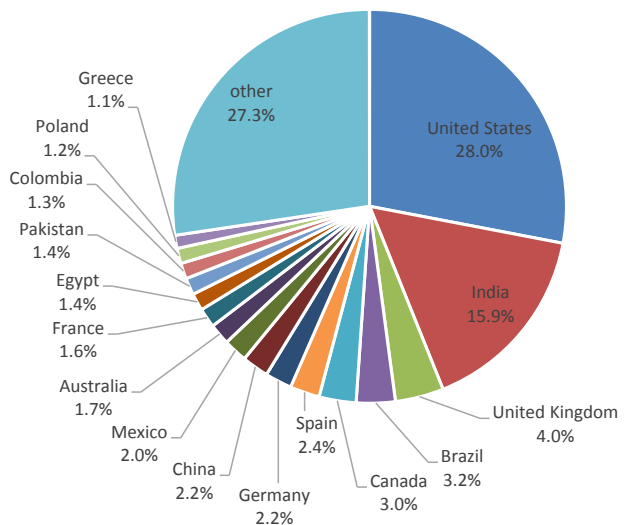


OCW is accessed by a broadly international population of educators and learners, with 55%–60% of all visitors accessing OCW from outside the U.S. in a typical month.

MITx is the Institute's interactive learning initiative that offers online versions of MIT courses on edX, a partnership in online education between MIT and Harvard University. MIT instructors teach these MITx courses, called "MOOCs," to learners around the world.

Learners must enroll in these courses, and they have the opportunity to earn certificates of achievement. Since the first MITx course was offered in August 2012, there have been more than 2.7M enrollments in MITx courses, with nearly 1.6 million participants (some people register for a course but then fail to follow through with any studies or use of course materials). Individual registrants come from more than 200 different countries.

Percent Registered by Country



Using the resources, platform, and pedagogical innovations of MITx, faculty also develop digital learning courses and modules for use in on-campus education.

International Study Opportunities

There are a broad range of global activities for students to choose from. These run the gamut from traditional study-abroad programs to innovative short term projects, but most are infused with the Institute's philosophy of *mens et manus*. In the spring of 2014, 43 percent of students graduating with a bachelor's degree, and 32 percent of students graduating with a master's degree reported having educational experiences abroad.

The following are examples of programs that provide students with experiences abroad:

Cambridge-MIT Exchange

Through the Cambridge-MIT Exchange Program (CME), undergraduate MIT students can spend their junior year studying at the University of Cambridge in England. The University of Cambridge consists of 31 colleges where students live and study in a supportive educational environment. Participating departments include Aeronautics and Astronautics; Biology; Brain and Cognitive Sciences; Chemical Engineering; Chemistry; Civil and Environmental Engineering; Earth, Atmospheric and Planetary Sciences; Economics; Electrical Engineering and Computer Science; History; Mathematics; Mechanical Engineering; and Physics.

Departmental Exchanges

The Department of Aeronautics and Astronautics offers study at the University of Pretoria in South Africa. The Department of Architecture has two exchange programs, one with Delft University of Technology in the Netherlands and the other with the University of Hong Kong. The Department of Materials Science and Engineering has exchange programs with Oxford University and Imperial College London. The Department of Nuclear Science and Engineering has an exchange program with the Imperial College London. The Department of Political Science has an exchange program with Sciences Po in Paris, France. The Department of Mechanical Engineering has an exchange program with ETH Zurich in Switzerland.

MIT-Madrid Program

The MIT-Madrid Program gives students the opportunity to study in Madrid for the spring term during their sophomore or junior year. Depending upon major and interests, students can choose science and engineering courses at the Universidad Politécnica de Madrid and/or humanities, arts, and social sciences courses at the Universidad Complutense de Madrid; instruction and coursework are in Spanish. These are leading universities in Spain, each with its own distinguished tradition and history. In addition to academic courses, students can participate in an internship during this program.

Singapore-MIT Undergraduate Research Fellowships (SMURF)

The SMART Centre has established a summer research internship programme: the SMURF programme (Singapore-MIT Undergraduate Research Fellows programme). It is open to all undergraduates at MIT, NTU, NUS, and SUTD and gives them the opportunity to engage in research at the SMART Centre over the summer. The SMURFs work in MIT Faculty supervisors' labs, actively participate in the research projects, and engage with postdoctoral scholars, graduate students, and other researchers. SMART hopes this opportunity excites them about research and they consider a career in research. Their research experiences are supplemented with numerous social activities that are arranged for them. Based on feedback from the students, the SMURFs greatly value their experiences at SMART and the community that forms among them.

Other Study Abroad Options

MIT students may also apply for admission directly to foreign institutions that offer study abroad programs and still graduate from MIT on time at the following universities: l'École Polytechnique in France, the London School of Economics in the UK, the University of New South Wales in Australia, and Tsinghua University in China. Students may also apply to study abroad programs administered by other U.S. institutions or outsider provider programs.

MIT International Science and Technology Initiatives

MIT International Science and Technology Initiatives (MISTI), MIT's primary international program, connects MIT students and faculty with research and innovation around the world. Working closely with a network of premier corporations, universities and research institutes, MISTI matches over 700 MIT students with internship, teaching, research and entrepreneurial opportunities abroad each year. After several semesters of cultural and language preparation on campus, MISTI students participate in rigorous, practical work experience in industry and in academic labs and offices. Projects are designed to align the skills and interests of the student with the needs of the host. MISTI also organizes the MISTI Global Seed Funds, which encourage MIT students to work on faculty-led international research and projects. MISTI programs are available in Africa, Belgium, Brazil, Chile, China, France, Germany, India, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Portugal, Russia, Singapore, Spain and Switzerland.

MISTI's approach to international education builds on MIT's distinctive traditions of combining classroom learning and hands-on experience in Undergraduate

Research Opportunities (UROPs), cooperative programs with industry, practice schools, and internships. In contrast to other universities' internationalization programs that mainly involve study abroad, MISTI matches individual students with work or research opportunities in their own fields.

<http://misti.mit.edu>

Here are a few examples from the more than 5,500 students MISTI has placed since it began by sending a handful of interns to Japan at the end of the 80s:

Chemical Engineering student Nathalia Rodriguez worked on gene therapy for muscular dystrophy at Genpole, a French biotech cluster.

Matthew Zedler, a Mechanical Engineering graduate, examined Chinese auto growth and energy at Cambridge Energy Research Associates in Beijing.

Physics major Jason Bryslawskij designed superconducting magnetic bearings for electric motors at Siemens in German. He wrote two patents at Siemens.

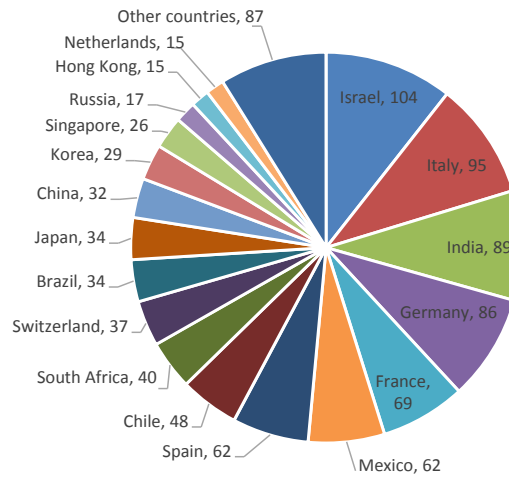
Ammar Ammar, an EECS undergrad, designed and tested a Google/YouTube project at Google Israel.



MISTI Programs and Start Year

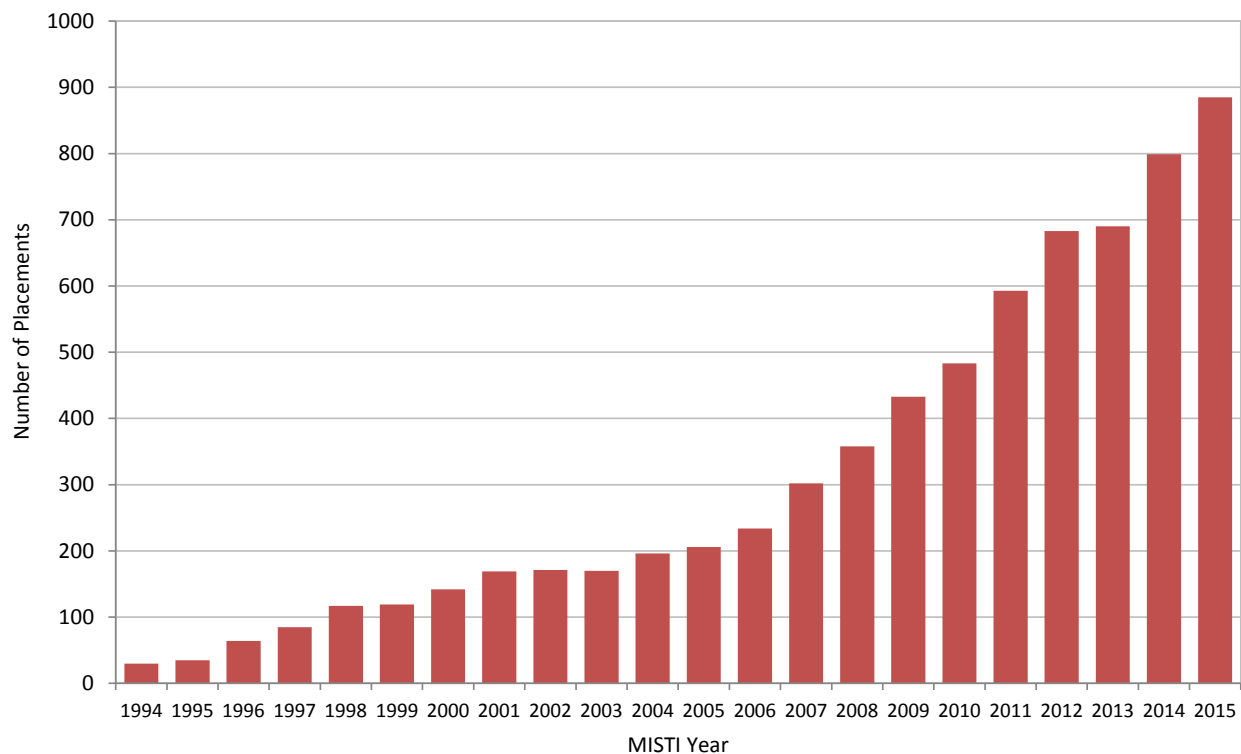
- Arab World, 2014
- Belgium, 2011
- Brazil, 2009
- Chile, 2011
- China, 1994
- France, 2001
- Germany, 1997
- India, 1998
- Israel, 2008
- Italy, 1999
- Japan, 1983
- Korea, 2012
- Mexico, 2004
- Netherlands, 2012
- Portugal, 2014
- Russia, 2012
- Singapore, 2012
- South Africa, 2012
- Spain, 2006
- Switzerland, 2010

MISTI Placements by Country, 2014–2015



In 2014–2015, there were MISTI placements in thirty-seven countries.

**MISTI Annual Internship Placements
1994–2015***



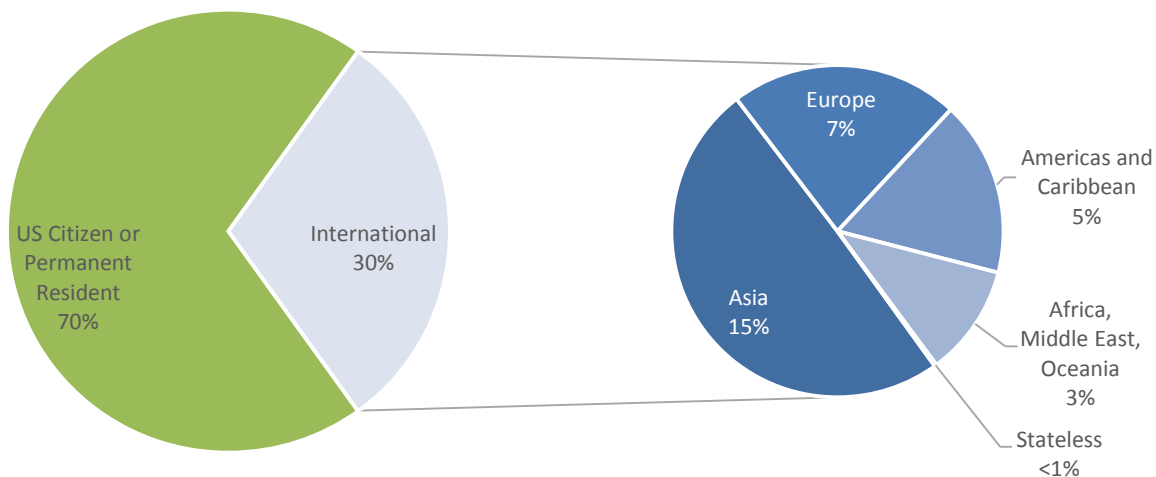
*MISTI year runs from September 1–August 31. 2015 represents the 2014–2015 year.

International Students

MIT has welcomed international students essentially since its inception. The first student from Canada came to MIT in 1866, the second year MIT offered classes. This student was followed by a steady stream of students from around the globe throughout the 19th century. By 1900, some 50 foreign-born students had traveled to Massachusetts for study; however, the number increased dramatically after World War II when an influx of these students began attending the Institute. The rapid rise of international students from East Asia, led by students from China, changed the demographics of this group beginning in the 1950s. Changes in immigration law in 1965 opened up the doors to a steadily increasing pool of international talent.

The United States has been the destination of choice for international students and scholars for the past 50 years. According to the Institute of International Education Open Doors 2015 report, the number of international students enrolled in U.S. colleges during the 2014–2015 academic year reached a record high of 974,926 students. MIT has the fourth highest number of foreign students of the institutions in Massachusetts. NAFSA: Association of International Educators produced an economic analysis based in part on Open Doors data that states that during the 2014–2015 academic year, international students and their dependents contributed \$30.5 billion to the U.S. economy through tuition, fees, and living expenses and support 373,381 jobs.

**Total Enrollment by Citizenship
and Geographic Region of Country of Citizenship
2015–2016**



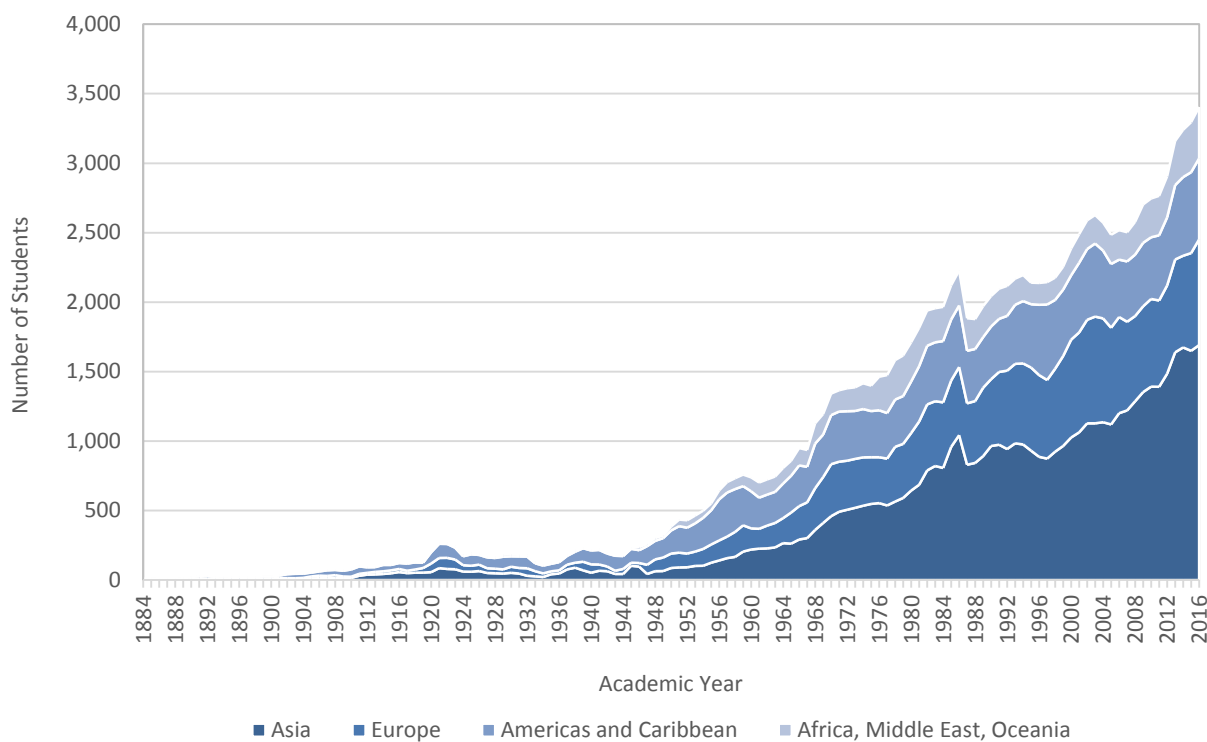
**International Undergraduate Students
Top Countries of Citizenship, 2015–2016**

Country	Count
China	57
India	32
Canada	24
South Korea	24
Brazil	23
Thailand	20
Saudi Arabia	18
United Kingdom	12
Mexico	10
Turkey	10

**International Graduate Students
Top Countries of Citizenship, 2015–2016**

Country	Count
China	634
India	304
Canada	234
South Korea	187
France	92
Singapore	87
Taiwan	70
Russia	70
Brazil	69
Germany	68

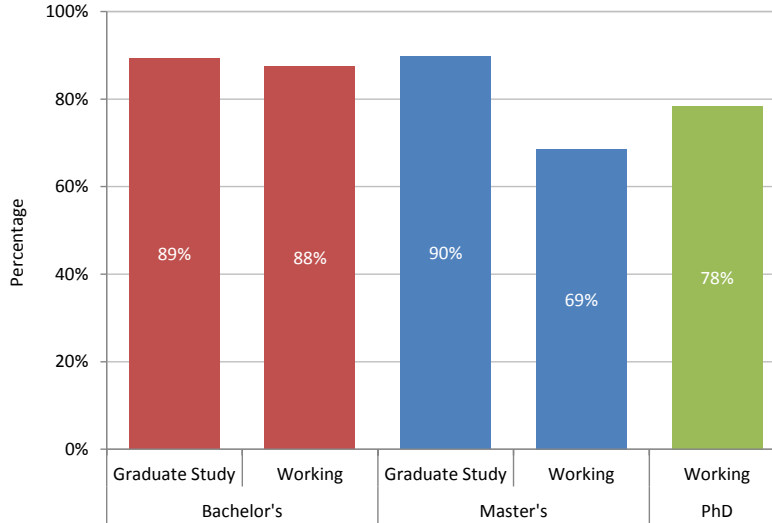
**International Students by Geographic Region of Country of Citizenship
1884–2016**



Many international students remain in the U.S. after graduation. The graph below shows the post-graduation plans of international students graduating

in 2015, as reported in a survey administered by MIT. Seventy-eight percent of international students plan to remain in the U.S. after graduation.

Percentage of 2015 International Student Graduates Remaining in the U.S. by Degree and Post-Graduation Plans



International Alumni Entrepreneurs

A 2009 Kauffman Foundation report on the Entrepreneurial Impact of MIT found the following:

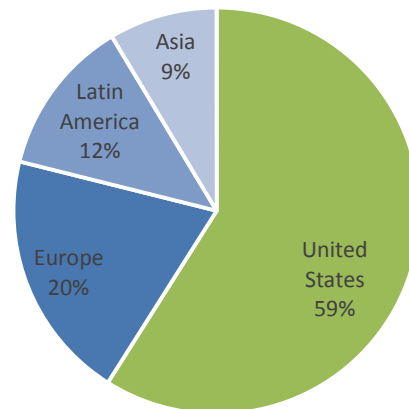
Alumni who were not U.S. citizens when admitted to MIT founded companies at different (usually higher per capita) rates relative to their American counterparts, with at least as many remaining in the United States as are returning to their home countries....

About 30 percent of the foreign students who attend MIT found companies at some point in their lives. This is a much higher rate than for U.S. citizens who attend MIT. We assume (but do not have data that might support this) that foreign students are more inclined from the outset to become entrepreneurs, as they had to seek out and get admitted to a foreign university, taking on the added risks of leaving their families and their home countries to study abroad. (MIT has only its one campus in Cambridge, Mass., and, despite collaborations in many countries, does not operate any degree program outside of the United States.) We estimate that about 5,000 firms were started by MIT graduates who were not U.S. citizens when they were admitted to MIT. Half of those companies created by "imported" entrepreneurs, 2,340 firms, are headquartered in the United States, generating their principal revenue (\$16 billion) and employment (101,500 people) benefits here.

Estimated Number of Companies Founded by International MIT Alumni

Location	Total
United States	2,340
Europe	790
Latin America	495
Asia	342

Location of Companies Founded by International MIT Alumni



International Alumni

MIT alumni and scholars have made extraordinary contributions in their home countries, the U.S., and the world. The following are some examples:

Kofi Annan, SM Management 1972

Kofi Annan, the seventh Secretary-General of the United Nations and recipient of the Nobel Peace Prize, was born in Kumasi, Ghana, and attended the University of Science and Technology in Kumasi before completing his undergraduate studies at Macalester College in St. Paul, Minnesota. He undertook graduate studies in economics at the Institut universitaire des hautes études internationales in Geneva, and earned his SM in Management as a Sloan Fellow at MIT. Annan worked for the World Health Organization and the Ghana Tourist Development Company, but has spent most of his career at the United Nations.

Mario Draghi, PhD Economics 1977

Mario Draghi is the president of the European Central Bank (ECB) which sets interest rates for the 17 countries in the Eurozone. He was previously the governor of the Bank of Italy and, in 2012, Forbes Magazine nominated him as the 8th most powerful man in the world. Shortly after becoming president of the ECB, he oversaw a €489 billion (\$640 billion), three-year loan program to European banks. He also stepped up the bond purchases from struggling Eurozone nations to help with the debt crisis. Draghi was born in Rome in 1947. He received a degree in economics from Università degli Studi, Rome in 1970 before attending MIT. While at MIT, he studied with Nobel winners Franco Modigliani and Robert Solow.

Benjamin Netanyahu, SB Architecture 1975, SM Management 1976

Currently serving his second term as Prime Minister of Israel, Benjamin Netanyahu was born in Tel Aviv, Israel and grew up in Jerusalem. He served as Israel's ambassador to the United Nations from 1984 to 1988, during which time he led the effort to declassify the United Nations' archive on crimes committed by Nazi Germany. Netanyahu, a member of the Likud party, was Israel's Prime Minister from 1996 until 1999. During his first term as Prime Minister, Netanyahu implemented policy that combined fighting terror with advancement of the peace process. Its cornerstone was the conclusion of well-measured

agreements with the Palestinians that insisted on reciprocity. During his three-year term, the number of terror attacks drastically decreased.

Ngozi Okonjo-Iweala, MCP 1978, PhD Planning 1981

Former Managing Director of the World Bank, Ngozi Okonjo-Iweala is a globally renowned Nigerian economist. She was the first woman to hold the position of Finance Minister in Nigeria. During her term from 2003 to 2006, she launched an aggressive campaign to fight corruption. She implemented a series of economic and social reforms, including a zero-tolerance policy for corruption; international and local governmental contract bidding; privatizing state-owned refineries; and the Extractive Industry Transparency Initiative, which aims to bring openness to the oil sector. Under her leadership, the country has tripled its reserves from \$7 billion to \$20 billion; the annual GDP grew at 6 percent; and inflation is down from 23 percent to 9.5 percent. Okonjo-Iweala started her career at the World Bank, where she was the first woman ever to achieve the positions of vice president and corporate secretary.

I. M. Pei, SB Architecture 1940

Ieoh Ming Pei, influential modernist architect and founder of the firm Pei Cobb Freed & Partners, was born in China in 1917. He completed his Bachelor of Architecture degree at MIT in 1940. Pei has designed more than 60 buildings, including the John Fitzgerald Kennedy Library in Boston, Massachusetts, the Grand Louvre in Paris, France, the Miho Museum in Shiga, Japan, the Bank of China Tower in Hong Kong, and the Gateway Towers in Singapore.

Tony Tan, SM Physics 1964

Following his degrees from MIT and his Ph.D. from the University of Adelaide in applied mathematics, Tan taught mathematics at the University of Singapore. Tan was elected to the Parliament of Singapore in 1979, and has served in numerous leadership positions in the Singapore government. In December 1991, Tan stepped down from the Cabinet to return to the private sector as the Overseas-Chinese Banking Corporation's Chairman and Chief Executive Officer. He rejoined the Cabinet in 1995 as Deputy Prime Minister and Minister for Defense. In August 2003, Tan became Deputy Prime Minister and Co-ordinating Minister for Security and Defense. Tan won the Singapore presidential election in 2011 and is currently serving as the 7th President of Singapore.

International Scholars

MIT hosts international scholars from around the world who come to the U.S. for teaching, research, collaboration, and other purposes. This diverse group of professionals includes visiting scientists, professors, artists, and scholars, as well as postdoctoral fellows and associates, lecturers, instructors, research associates and scientists, and tenure-track faculty. During the year July 1, 2014 through June 30, 2015, The International Scholars Office (ISchO) served 2,403 international scholars affiliated with MIT and their accompanying family members (“international” is defined as non-U.S. citizen, non-U.S. permanent resident).

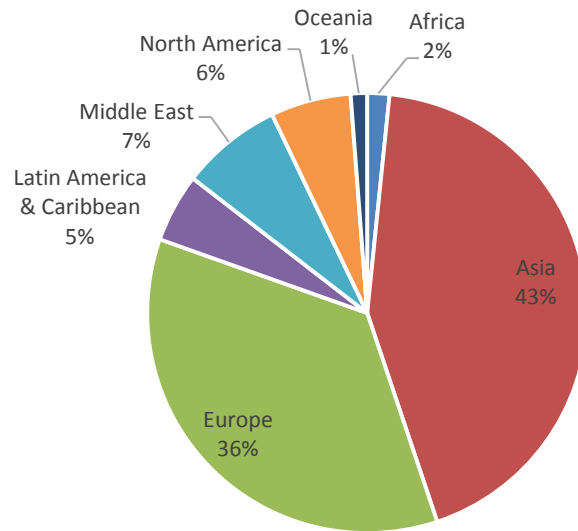
This reflects an increase of 4 percent over last year (2,305). According to the most recently published Institute of International Education Open Doors report (2014), MIT ranked 11th nationally with regard to the numbers of international scholars at U.S. institutions. Postdoctoral associates and postdoctoral fellows accounted for 59 percent of MIT’s international scholars.

Foreign national scholars came to MIT from 93 different countries, with the highest numbers coming from China, South Korea, India, Germany, Canada, Japan, Italy, Israel, Spain and the UK. The top ten countries of origin of the entire international scholar population in the U.S. are roughly the same. Scholars from these top 10 countries constituted 64 percent of MIT’s international scholar population. Seventy-six percent of international scholars at MIT were men and 24 percent were women. The greatest number of international scholars came to join departments in the School of Engineering, followed by the School of Science, interdisciplinary laboratories and centers, and the Sloan School of Management.

**International Scholars
Top Countries of Origin, 2014–2015**

Country	Count
China	445
South Korea	177
India	161
Germany	144
Canada	142
Japan	126
Italy	101
Israel	100
Spain	80
United Kingdom	73

**International Scholars
by Geographic Region, 2014–2015**



Selected Projects

Toward hack-proof RFID chips

MIT researchers have developed a new type of radio frequency identification (RFID) chip that is extremely difficult to hack. The chip is designed to prevent side-channel and a “power glitch” attacks. If such chips were widely adopted, it could mean that an identity thief couldn’t steal your credit card number or key card information by sitting next to you at a café, and high-tech burglars couldn’t swipe expensive goods from a warehouse and replace them with dummy tags.

Side-channel attacks analyze patterns of memory access or fluctuations in power usage when a device is performing a cryptographic operation, in order to extract its cryptographic key. One way to thwart side-channel attacks is to regularly change secret keys. In that case, the RFID chip would run a random-number generator that would spit out a new secret key after each transaction. A central server would run the same generator, and every time an RFID scanner queried the tag, it would relay the results to the server, to see if the current key was valid.

A power glitch attack is when an RFID chip’s power is repeatedly cut right before it changed its secret key. An attacker could then run the same side-channel attack thousands of times, with the same key. Two design innovations allow the researchers’ chip to thwart these attacks: One is an on-chip power supply whose connection to the chip circuitry would be virtually impossible to cut, and the other is a set of “nonvolatile” memory cells that can store whatever data the chip is working on when it begins to lose power.

The work was funded by Texas Instruments and the Japanese automotive company Denso.

<http://bit.ly/1NQQKDy>

A virtual “guide dog” for navigation

MIT researchers have developed a low-power chip for processing 3D camera data that could help visually impaired people navigate their environments.

The chip consumes only one-thousandth as much power as a conventional computer processor executing the same algorithms. Using their chip, the researchers also built a prototype of a complete navigation system for the visually impaired. About the size of a binoculars case and similarly worn around the neck, the system uses an experimental 3D camera from Texas Instruments. The user carries a mechanical Braille interface developed at MIT’s Computer Science and Artificial Intelligence Laboratory (CSAIL), which conveys information about the distance to the nearest obstacle in the direction the user is moving.

The work was sponsored by the Andrea Bocelli Foundation and Texas Instruments, and the prototype chips were manufactured through the Taiwan Semiconductor Manufacturing Company’s University Shuttle Program.

<http://bit.ly/1PgHoTz>

A new way to store solar heat

A team of researchers at MIT has developed a new polymer film that can store solar energy during the day and release it later as heat, whenever it’s needed.

The finding, by Jeffrey Grossman, postdoc David Zhitomirsky, and graduate student Eugene Cho, is described in a paper in the journal *Advanced Energy Materials*. The key to enabling long-term, stable storage of solar heat, the team says, is to store it in the form of a chemical change rather than storing the heat itself. Whereas heat inevitably dissipates over time no matter how good the insulation around it, a chemical storage system can retain the energy indefinitely in a stable molecular configuration, until its release is triggered by a small jolt of heat (or light or electricity).

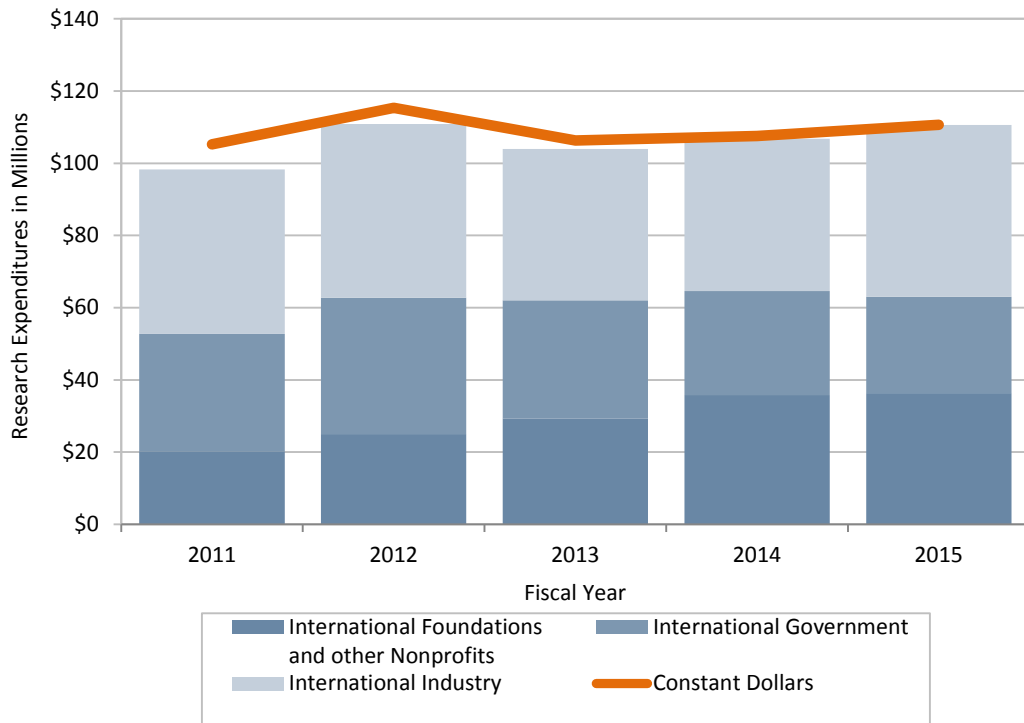
The work was supported by a NSERC Canada Banting Fellowship and by BMW.

<http://bit.ly/1OeOYNY>

Campus Research Sponsored by International Organizations

International Organizations Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2011–2015

International Sponsor Type	2011	2012	2013	2014	2015
Foundations and other nonprofits	20,233,545	25,025,346	29,381,412	35,830,415	36,301,791
Government	32,471,318	37,712,878	32,651,167	28,803,960	26,712,520
Industry	45,603,282	48,133,890	41,922,158	42,127,804	47,606,652
Total	98,308,146	110,872,115	103,954,737	106,762,179	110,620,964
Constant dollars*	105,240,028	115,311,422	106,347,034	107,539,385	110,620,964



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2015 equaling 100.

Section 8

Service to Local and World Communities

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Service to Local and World Communities

Founded with the mission of advancing knowledge to serve the nation and the world, MIT has been strongly committed to public service from its start. While MIT faculty, students, and staff regularly engage in conventional projects such as raising money for hurricane victims, renovating old housing, or restoring local nature reserves, MIT's scientific and technological orientation gives much of its public service outreach a particular emphasis. Many of its public service programs are specifically devoted to inventing new technologies and applying new knowledge that will advance social well-being.

Priscilla King Gray Public Service Center

The Priscilla King Gray Public Service Center (PSC) helps MIT achieve its mission of working wisely, creatively, and effectively for the betterment of humankind. Through its programs, they provide encouragement, advice, logistical support, and funding to help students engage in meaningful and effective public service projects, working with communities in the greater Boston area, throughout the United States, and around the world.

The PSC goal is to enrich the MIT education for students through hands-on, real-world opportunities that complement the innovative culture of MIT. PSC programs (described below) are designed to help students apply classroom learning, develop new skills, and understand the complexities of resolving community challenges.

<http://web.mit.edu/mitpsc/>

PSC Fellowships Program

MIT students tackle a great variety of human and environmental challenges in communities around the world through this program. Participating students build their skills and reflect on their experiences to enhance classroom learning. Students can work individually or as part of a team on projects during IAP, summer, and the academic year. This past year, 45 PSC fellows tackled some of the most pressing

issues in the United States and abroad, working in sectors such as agriculture, water and sanitation, climate change, community development, assistive technology, education, environmental sustainability, food and agriculture, health and health technology, technology dissemination, and urban planning.

IDEAS Global Challenge

Through this annual innovation and social entrepreneurship competition, students form teams to work with a community partner to design and implement innovative projects that improve the quality of life in communities around the world. In 2015, grants were awarded to 11 teams working in sectors such as energy, mobile technology, health and medical devices, water and sanitation, education, and agriculture. Winners of last year's awards continue to advance their ideas, including testing a malaria diagnostic device, altering cell behavior to fight diabetes, and creating simple-to-read maps for the placement of electrical microgrids in rural areas.

ReachOut

Through this semester-long program, MIT students help Cambridge children foster a love of reading and mathematics. This past winter, two ReachOut tutors helped with program development for East End House's growing middle school program. During the spring semester, 29 MIT student tutors helped children with math and reading in the local community at our two partner sites, East End House and Cambridge Community Center.

Community Service Work-Study

This program enables MIT students to give back to the community while earning a paycheck during the semester, summer, or winter break. Students who qualify for Federal work-study are able to add to their work experience while assisting nonprofit organizations with finding creative solutions to the problems they face. In spring 2015, work-study students staffed a local homeless shelter, created communication materials for a lead-poisoning prevention program, served as advocates for low-income clients, and tutored Boston high school athletes. Through a partnership between Community Service Work-Study and the Externship program, four students traveled to Los Angeles this past winter to design material for a STEM program with the i.am.angel Foundation.

CityDays

Since July 2014, CityDays events have engaged hundreds of MIT students, staff, and faculty with the local community. Many of the volunteers participated in multiple CityDays events, and PSC developed relationships with active student groups on campus. Sports teams, living communities, service groups, and fraternities and sororities have all participated.

Four Weeks for America

This program enables MIT students to spend IAP working with Teach for America teachers on science and math projects in classrooms in small rural areas or big inner cities while learning about educational change and policy. In 2015, 13 MIT undergraduate students worked as classroom assistants for new STEM teachers and provided all types of support from in-classroom help and after school tutoring to curriculum development and classroom data analysis. Several students worked on additional projects including a renewable energy science fair, a college exposure and admissions program, and innovative lab experiments.

Alternative Spring Break

Alternative Spring Break enables MIT students to spend spring break participating in service in various locations around the country. In March 2015, 23 MIT students participated in three projects. One group went to Crotched Mountain School in New Hampshire, where MIT students worked with children with severe disabilities. Another group went to the Center for Environmental Transformation in Camden, NJ, where MIT students worked with a variety of community organizations on sustainable agriculture and community development. The third group participated in PSC's CityWeek, in partnership with the local community center Margaret Fuller House. MIT students stayed on campus and spent their days tutoring children, cleaning the center, and learning about this multifaceted and exceptional community resource right outside MIT's campus.

LEAP Grants

Learn, Explore, Act, & Prepare (LEAP) Grants provide MIT students with funding to carry out a service project, volunteer day, or philanthropy event in the United States. LEAP grants allow students learn about service and social responsibility or build their skills to tackle a community challenge.

Freshman Urban Program

Through this week-long freshman pre-orientation program, incoming MIT students can help others while exploring their new neighborhood, learning about community challenges, and making friends. Last year, the program introduced 26 incoming students to MIT and the surrounding community through service activities and the discussion of social issues. The program also engaged 11 upperclassmen as counselors and coordinators. Freshman Urban Program participants volunteered with 16 agencies—such as the Charles River Conservancy and Bridge over Troubled Waters—and explored how issues like hunger and homelessness affect our community.

Office of Government and Community Relations

Since its founding, MIT has maintained a commitment to serving the local community as both a resource for education and technology and as a good neighbor. Through the Office of Government and Community Relations (OGCR), MIT works collaboratively with dozens of Cambridge nonprofits that address local challenges and opportunities such as meeting the needs of underserved populations, youth programs, and environmental sustainability. The Institute supports these organizations by providing direct financial support as well as in-kind resources including facility use, faculty and staff expertise, and volunteer engagement. In addition, OGCR collaborates with the MIT Public Service Center and MIT Community Giving to oversee the MIT Community Service Fund (CSF). The CSF provides support for nonprofits where MIT volunteers are at work and encourages the creation of new community service projects by providing grants to MIT affiliates.

Service to the community is not just centralized in one office at MIT—the Institute's various Departments, Labs and Centers have a diverse array of programs that support our host community.

Office of Digital Learning

The Office of Digital Learning (ODL) advances MIT's longstanding tradition of service to society with collaborations that bring technology-enabled pedagogical innovation to classroom education and online learning at home and abroad. Primarily through its Strategic Education Initiatives unit, ODL engages with institutions and governments at many levels to help strengthen teaching and learning in a variety of settings.

Massachusetts Community College Project

The Office of Digital Learning, through its Strategic Educational Initiatives unit, is taking the lead in developing collaborations with community colleges. These projects include curriculum development in areas such as advanced manufacturing and entrepreneurship, and online learning using edX and other MIT technologies. The design of these projects reflects the MIT *mens et manus* philosophy of blending online/virtual instruction with hands-on learning. With funding from the federal Trade Adjustment Assistance Community College and Career Training (TAACCCT) Grant Program, ODL is working with 15 Massachusetts community colleges to develop blended courses in advanced manufacturing. Other collaborations are in the proposal or design stages.

MIT-Woodrow Wilson Academy of Teaching and Learning

The MIT pre-K-through-12 ("PK12") Initiative in ODL, with collaborators across MIT, is designed to combine MIT's *mens et manus* approach to learning with recent breakthroughs in cognitive science and digital learning to help develop and support excellent STEM (Science, Technology, Engineering, Math) teachers and school leaders. The PK12 initiative was launched through the work of a faculty group, facilitated by ODL, which articulated the foundational principles for this effort: To change the world through learning with access to quality STEM education for all, and to change the world of learning through rigorous research. The PK12 Initiative has been bootstrapped by \$9.9 million in seed funding from the Woodrow Wilson National Fellowship Foundation for collaboration aimed at supporting

teachers in their efforts to use emerging digital learning tools and environments, especially in STEM areas. The effort will promote new ideas, technologies, and curricula along with research related to educator preparation with a focus on STEM subjects for students from pre-kindergarten through the senior year of high school.

Abdul Latif Jameel Poverty Action Lab

The Abdul Latif Jameel Poverty Action Lab (J-PAL) is a global network of over 120 researchers from leading universities who use randomized evaluations to answer critical questions in the fight against poverty. J-PAL was founded on the belief that development programs can be made more effective, creating positive change in the lives of the poor, if policymakers have access to rigorous scientific evidence of what works.

J-PAL's mission is to reduce poverty by ensuring that policy is informed by scientific evidence. We do this through three main activities: (1) increase scientific evidence on poverty reduction through randomized evaluations, (2) promote a culture of evaluations through training and facilitating the use of evidence in the policymaking process, and (3) encourage the use of rigorous research findings in the design and scale-up of poverty alleviation programs through outreach, promotion, and technical advising.

J-PAL was founded at MIT in 2003 as a research institute in the Department of Economics. In addition to its headquarters at MIT, J-PAL has expanded to six regional offices hosted by local universities in Africa (University of Cape Town), Europe (Paris School of Economics), Latin America (Pontificia Universidad Católica de Chile), North America (MIT), South Asia (Institute for Financial Management & Research), and Southeast Asia (University of Indonesia). Within each region, J-PAL works across eight sector areas, including Agriculture, Crime & Criminal Justice, Education, Environment & Energy, Finance & Microfinance, Health, Labor Markets, and Political Economy & Governance.

Research

J-PAL affiliates have conducted more than 600 randomized evaluations in over 60 countries. Recent research by J-PAL affiliates includes: an evaluation by Banerjee (MIT), Duflo (MIT), Glennerster (J-PAL), and Kinnan (Northwestern) on the impact of increased access to microcredit on the economic and social well-being of women and their families in India; a six-country study by Banerjee (MIT), Duflo (MIT), Goldberg (IPA), Karlan (Yale), Osei (University of Ghana), Pariente (Princeton), Shapiro (Princeton), Thuysbaert (Ghent University), and Udry (Yale) that found that a comprehensive livelihood program for the poor was a cost-effective and lasting way to boost livelihoods, income, and health; and an evaluation by Olken (MIT), Onishi (World Bank), and Wong (World Bank) that found that community block grants improved health and education in Indonesian villages, and adding performance incentives sped up improvements in health.

Capacity Building

J-PAL also aims to increase the capacity of governments, NGOs, and other organizations to produce their own evidence to inform effective development policy. J-PAL has equipped more than 6,000 practitioners with the expertise to conduct their own rigorous evaluations through training courses and joint research projects.

Policy Outreach

J-PAL affiliates and staff analyze and disseminate research results and build partnerships with policymakers to ensure that policy is informed by evidence and to scale up programs that are found to be highly effective. Such programs have included environmental audit reforms, school-based deworming, remedial education, free insecticidal bednets, chlorine dispensers for safe water, skills training for police officers, conditional community block grants, and improved distribution of subsidized rice. Programs that were found to be successful by J-PAL affiliates and then scaled up in different parts of the world have reached over 200 million people.

J-PAL North America

J-PAL North America (NA), one of J-PAL's six regional offices, is also based at MIT. J-PAL NA works to improve lives by ensuring that policy in the region is informed by scientific evidence. J-PAL NA collaborates with decision-makers at the city, state, and federal level, and with a variety of social organizations, to share policy lessons, conduct trainings, and encourage evaluation. J-PAL NA's work spans a wide variety of areas including: Crime Prevention, Education, Energy Conservation, Financial Literacy, Health Care Delivery, Housing Mobility, Labor Markets, and Political Participation. J-PAL affiliates are conducting or have completed over 110 randomized evaluations in the region. J-PAL NA is led by two Co-Scientific Directors: Amy Finkelstein (Ford Professor of Economics, MIT) and Lawrence Katz (Elisabeth Allison Professor of Economics, Harvard University).

Local Programs

Amphibious Achievement

Amphibious Achievement is an MIT student group that mentors high school students in the Boston-Cambridge area in both athletics and academics. Under the guidance of MIT student coaches/tutors, Amphibious Achievers train to row and swim competitively while also working on critical reading techniques, math problem solving, and grammar comprehension in an SAT-based curriculum.

<http://amphibious.mit.edu/>

Cambridge Science Festival

The annual Cambridge Science Festival, the first of its kind in the United States, is a celebration showcasing Cambridge as an internationally recognized leader in science, technology, engineering, and math. The festival is presented by the MIT Museum in collaboration with the City of Cambridge, community organizations, schools, universities, and businesses. A multifaceted, multicultural event held every spring, the festival makes science accessible, interactive, and fun, while highlighting the impact of science on all our lives.

<http://www.cambridgesciencefestival.org/>

Edgerton Center—K–12 Programs

The Edgerton Center continues the learning-by-doing legacy of “Doc” Edgerton. The Center’s K–12 programs educate, inspire, and motivate kindergarten through 12th grade students through hands-on science and engineering challenges with the aim of increasing students’ curiosity and desire to pursue these fields in their future. Concentrating in the Greater Boston area, with selected out-of-state and foreign endeavors, the Edgerton Center’s multi-faceted approach supports over 150 on-campus classroom workshops annually, intensive summer programs, innovative curriculum and professional development workshops for teachers. The Edgerton Center instructors mentor faculty and students in local public schools as well. In all aspects of these programs, MIT students are closely involved. All of the programs are provided at no or minimal cost.

Educational Studies Program

Founded by students in 1957, the MIT Educational Studies Program (ESP) shares knowledge and creativity with local high school students in the Boston, Cambridge, and MIT communities. Through an extensive offering of academic and non-academic classes, ESP is dedicated to providing a unique, affordable educational experience for motivated middle school and high school students. ESP courses are developed and taught by MIT students, alumni, faculty, and members of the community.

<http://esp.mit.edu/>

Giving Tree

The MIT Giving Tree allows students, alumni, faculty, staff, and friends to provide gifts to local children and families each holiday season. The MIT Public Service Center works with several campus groups, along with hundreds of individuals across campus to collect gifts for 12 local agencies serving low-income children. This program provides MIT a means to expand our ethic of caring to local children and families.

World Programs

Comprehensive Initiative on Technology Evaluation

The Comprehensive Initiative on Technology Evaluation (CITE) at MIT is the first-ever program dedicated to developing methods for product evaluation in global development. CITE evaluates products’ suitability, scalability, and sustainability, and seeks to integrate these criteria to develop a deep understanding of what makes products successful in emerging markets. CITE’s evaluations provide evidence for data-driven decision-making by development workers, donors, manufacturers, suppliers, and consumers themselves. CITE is a five-year program funded by USAID’s Global Development Lab and led by the Department of Urban Studies and Planning.

<http://cite.mit.edu/>

D-Lab

MIT D-Lab is building a global network of innovators to design and disseminate technologies that meaningfully improve the lives of people living in poverty. The program’s mission is pursued through interdisciplinary courses (2019 developed to date, about a dozen offered each year), technology development, and community initiatives, all of which emphasize experiential learning, real-world projects, community-led development, scalability, and impact assessment. Founded by Amy Smith, Senior Lecturer in Mechanical Engineering, D-Lab has developed a range of technologies and processes including community water testing and treatment systems, human powered agricultural processing machines, medical and assistive devices for global health, and clean-burning cooking fuels made from waste. All D-Lab classes and projects are connected to communities around the world in countries including Brazil, Nicaragua, Honduras, Guatemala, El Salvador, Haiti, Ghana, Lesotho, Nigeria, Tanzania, Uganda, Zambia, Cambodia, Nepal, India, and the Philippines. In addition to its course offerings and field-work, D-Lab is home to research groups including the Biomass Fuel and Cookstoves Group, the Mobile Technology Group, and the Off-Grid Energy Group. D-Lab has also spearheaded an initiative called Lean Research, promoting principles for human-centered research.

<http://d-lab.mit.edu/>

D-Lab Scale-Ups

D-Lab Scale-Ups was established in 2011 to identify and support technologies with potential for wide-scale poverty alleviation. The program includes an accelerator for MIT social entrepreneurs, a technical assistance program, research and development, and collaboration with industry. As of 2014, the Scale-Ups Fellowship program has supported 2316 social entrepreneurs working in sectors including health care, waste recycling, water sanitation, solar energy, and agriculture. The Scale-Ups fellows have launched ventures in less-industrialized markets in Africa, Central and South America, and Asia. Scale-Ups' technical assistance program for agricultural waste charcoal briquette enterprises in East Africa is facilitated by the Harvest Fuel Initiative, a collaborative effort by D-Lab and New York-based nonprofit The Charcoal Project. Research and development work focuses on solar lighting, biomass fuel and cookstoves, water transportation and storage, and agriculture. In the fall of 2014, D-Lab Scale-Ups launched the Practical Impact Alliance at MIT to promote collaborative action and shared learning among corporations, academic institutions, social ventures, and nongovernmental organizations in order to scale market-driven poverty solutions worldwide. Each year since 2012, Scale-Ups has led the organization of the MIT Scaling Development Ventures conference.

<http://d-lab.mit.edu/scale-ups/overview/>

International Development Innovation Network

The International Development Innovation Network (IDIN) is building a diverse, international, network of innovators to define development problems, prototype solutions to these challenges, perform comparative evaluations, move the most promising solutions forward, and incubate ventures to disseminate the solutions. At the core of IDIN is a network of nearly over 54,200 inventors, technologists, and social entrepreneurs from almost 530 countries around the world. IDIN is supporting and building this network through hands-on design summits, focused entrepreneurship training modules, micro-grants, and networking within and outside the network. IDIN also includes research, monitoring, and evaluation functions to document and assess its work to ensure that best practices are identified and supported. In addition to MIT, IDIN consortium institutions include Olin College of Engineering, Colorado State University, University of California-Davis, Kwame Nkrumah University of Science and Technology (Ghana), Singapore Polytechnic, the ECHO East Africa Impact Center (Tanzania), and the National Technology Business Center (Zambia), as well as three IDIN innovation centers in Brazil, Uganda, and Tanzania.

<http://d-lab.mit.edu/idin/>

Legatum Center for Development and Entrepreneurship

The Legatum Center for Development and Entrepreneurship at MIT was founded on the belief that economic progress and good governance in low-income countries emerge from entrepreneurship and innovations that empower ordinary citizens. The center administers a highly competitive fellowship program for MIT graduate students who intend to launch innovative and inclusive for-profit enterprises in developing countries. In addition to supporting the Legatum Fellows, the Legatum Center aims to catalyze entrepreneurship for broad-based prosperity by administering programs including case writing, research, articles, lectures, conferences, and seed grants.

<http://legatum.mit.edu/>

Selected Projects

Cleaning water without the grid

Amos Winter describes one of the most important aspects of his job as “detective work.” That’s what he, PhD candidate Natasha Wright, and fellow researchers did for two years before coming up with a potential solution to issues of clean-water access in India.

It paid off. Their research team, sponsored by the MIT Tata Center for Technology and Design and its partner, the Indian firm Jain Irrigation Systems, won the United States Agency for International Development (USAID)’s Desal Prize with their design of a solar-powered electro dialysis desalination system.

The detective work began when Jain Irrigation pointed out that small-scale farmers in India who use Jain’s irrigation systems often lack access to safe drinking water. Winter, Wright, and others on the Tata Center team spent two years meeting with farmers and village dwellers trying to understand the reason for drinking water shortages in rural Indian communities.

The team identified a generally overlooked contaminant in India’s water: salt. By removing salt from water sources, the team could more than double the groundwater available to villagers for drinking.

The announcement of the USAID Desal Prize competition hit shortly after the team published a paper on the importance of desalination to clean drinking water. The team took their prototype system to the competition and in a pool of almost 70 applicants, they won. In fact, they were the only entry to meet all of USAID’s specifications for flow rate and salinity.

The win was game-changing. According to Winter, the Desal Prize has seriously accelerated the typical development timeline for a project like this. Winning the prize has connected him and Wright with other major players in the clean water space, and international expertise provided by USAID has put more potential locations for the new desalination system on the team’s radar. One of them is Gaza. “It’s pretty exciting,” Winter says, “because the needs and requirements for off-grid desalination [in the Middle East] are very similar to those in India.”

<http://bit.ly/1qIsaRg>

Empowerment through mobile technology and co-design

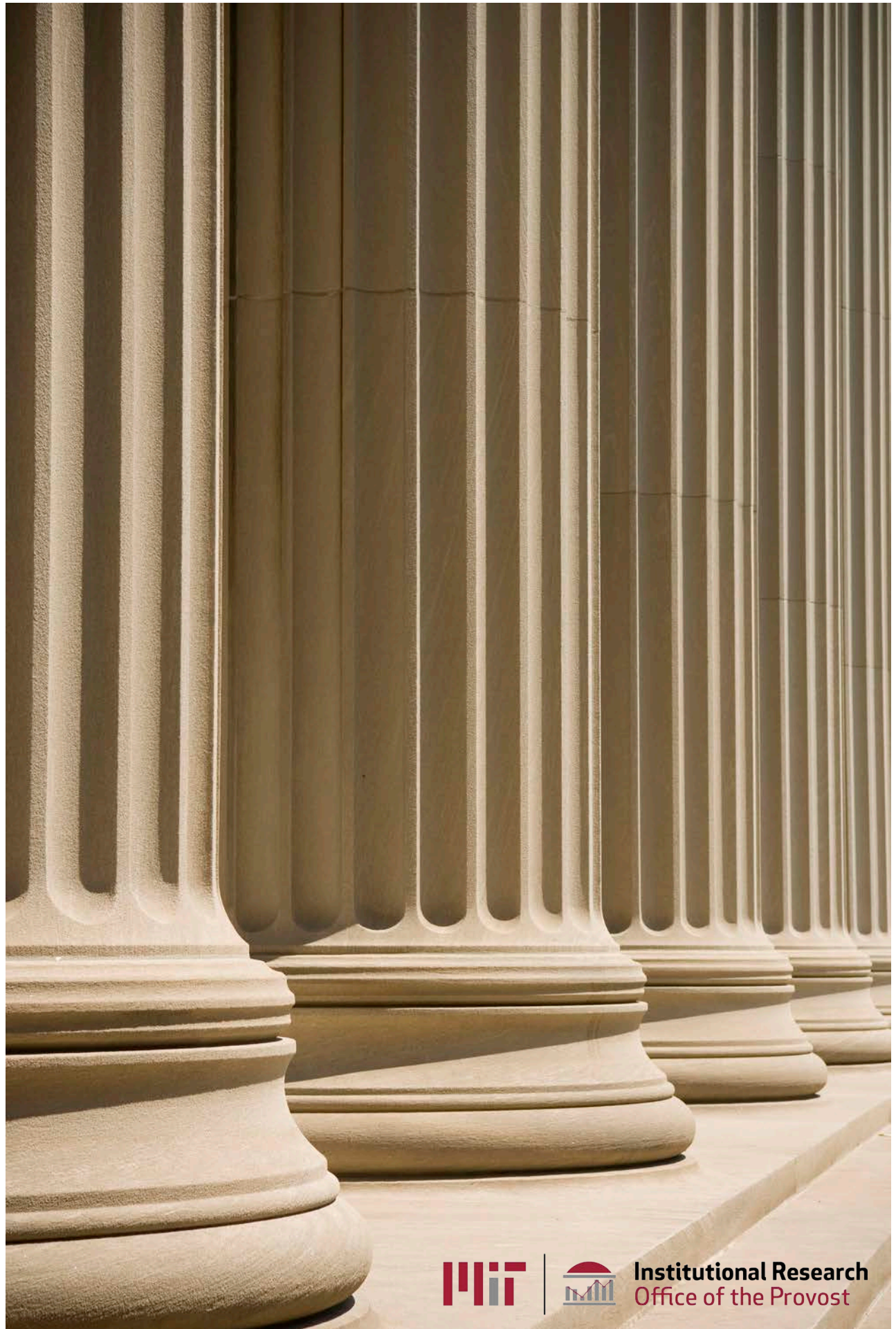
“Far and away the best prize that life has to offer is the chance to work hard at work worth doing,” Theodore Roosevelt once said in a speech in 1903. MIT senior in computer science Beth Hadley takes these words to heart. She has been a pivotal force behind InstaAid, an iPad application that enables residents at The Boston Home (TBH) to access assistance from any area of the facility, thus increasing their safety and quality of life.

During the fall of 2014, in the course Principles and Practices in Assistive Technologies, or PPAT, Hadley and her classmates, senior Laura D’Aquila and junior Tanya Talkar, formed a team with Margaret Marie, a TBH resident, to design an application that transformed the nurse call system at the home. For many residents of the home, calling for help is not a simple task. Most residents have limited mobility due to conditions such as amyotrophic lateral sclerosis (ALS), making it difficult, and many times impossible, to reach the help button wired to the wall. Many residents, however, already use iPads attached to their wheelchairs.

While the first iteration of the application was developed during the PPAT class, Hadley turned it into her senior thesis project and continued to improve it. She tested and revised several prototypes and incorporated feedback from TBH residents and staff throughout, turning an experimental product into a robust and sustainable call system downloadable from the Apple App Store. The application transforms the process of providing help to residents. With two interfaces, one for the resident, and one for the nurse, users can request water, aid, or signal an absolute emergency at the touch of a button, whether they are in their room or even away from the home’s premises. The custom notification helps nurses identify real emergencies and dispatch the right personnel for each call.

InstaAid is one of the first mainstream mobile communication technology that meets the dynamic communications needs of differently-abled individuals—the interface is designed to accommodate for visual, motor, and cognitive challenges.

<http://bit.ly/1qIsf7s>



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