

NATIONAL GEOGRAPHIC

REPRINTED FROM THE MAY, 1962, MAGAZINE

Telephone a Star

By ROWE FINDLEY
National Geographic Staff



NATIONAL GEOGRAPHIC

Society

16th & M Streets N.W.

Washington 6, D. C.



National Geographic Magazine

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Telephone a Star

*Communications satellites
will relay messages across
earth's oceans and continents*

By **ROWE FINDLEY**

National Geographic Staff

MY FIRST THOUGHT was of a hospital operating room.

There were the surgeons in spotless caps and gowns, bending intently over their work. There were the immaculate walls, the well-scrubbed floor, the strange-looking machines with their mazes of tubes and wires. Only the figure on the operating table was missing.

I was in a Bell Telephone Laboratories facility at Hillside, New Jersey, and my guide, engineer Robert H. Shennum, soon led me to a corner of the room where I beheld the patient.

It was a gleaming white sphere as big around as a truck tire. Hundreds of gemlike rectangles sparkled on its sleek surface, and around its middle ran rows of tiny windows. An extensible mast crowned by a wire coil sprouted from its top.

"Take a good look now," Mr. Shennum said. "Where it's going, you won't get another chance."

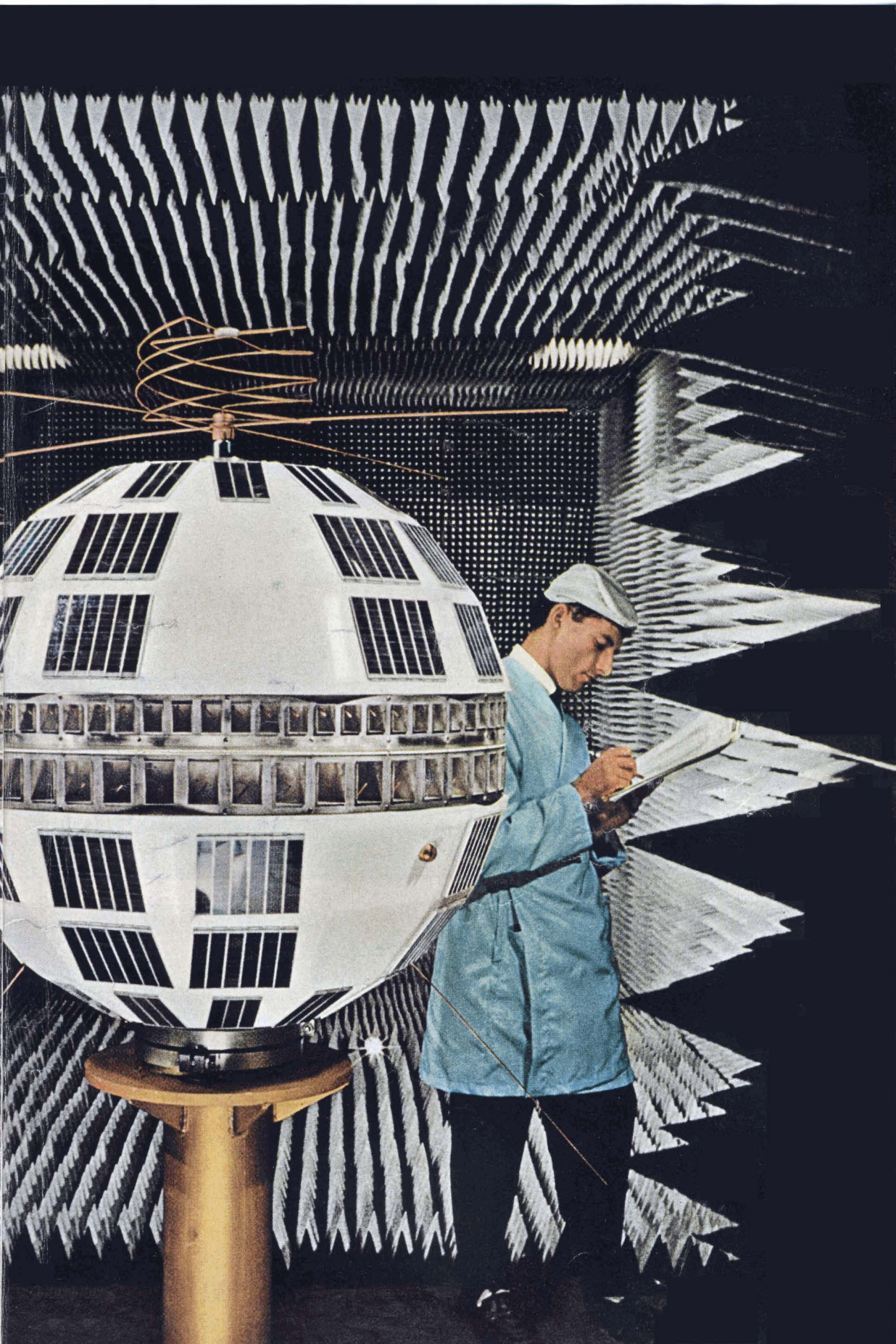
He was right, I won't see the sphere again. Instead I'll probably talk to it—or something very much like it. Chances are you will, too, for that gleaming ball with all the windows is Telstar,

Mock-up of Telstar, a communications satellite scheduled for launching from Cape Canaveral in the next few weeks, gets an antenna check in a Bell Laboratories plant in Hillside, New Jersey. In space, Telstar will relay telephone, television, and telegraph messages across the Atlantic.

Toothed plastic walls of the room absorb all but direct signals to Telstar's receiver, duplicating conditions in space. Technician checks test data.

KODACHROME BY NATIONAL GEOGRAPHIC
PHOTOGRAPHER ROBERT B. GOODMAN © N.G.S.





forerunner of commercial communications satellites designed to relay telephone messages across the world from a point thousands of miles in space. Of all the space objects launched so far, these satellites are the first that millions of people will actually use.

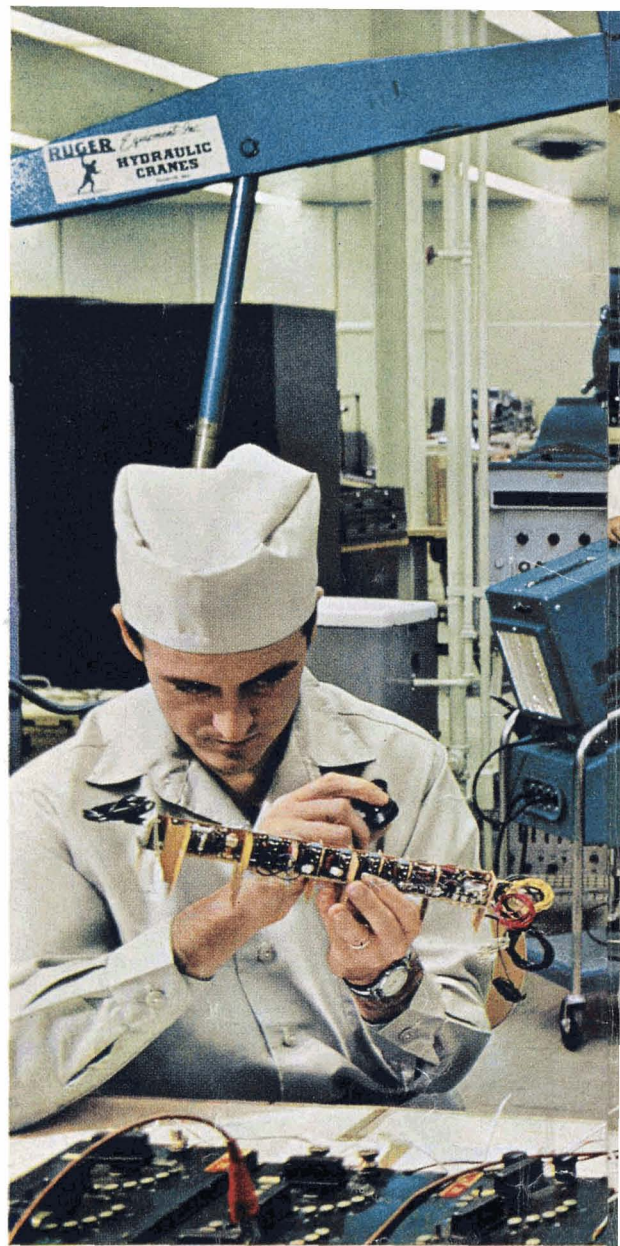
Automatic Phones Take to Space

Telstar—named for telecommunications and star—represents the electronic ingenuity of Bell Laboratories at Murray Hill, New Jersey, the research and development arm of American Telephone and Telegraph Company. Thus, from the birthplace of such miracles as the transistor, solar cells, and network television, comes another revolutionary device in the science of communications—a telephone relay station in space.*

And Telstar will have company in the sky. The National Aeronautics and Space Administration has contracted with the Radio Corporation of America to build a communications satellite called Relay, almost ready for launching, and with Hughes Aircraft Company for another known as Syncom. General Electric Company and Bendix Corporation are producing still another, named Advent, for the Department of Defense.

But several things distinguish Telstar from

*For a history of telephone communications—from conception to the age of space—see the following articles in NATIONAL GEOGRAPHIC: "Prehistoric Telephone Days," March, 1922, by Alexander Graham Bell, the only biographical article ever written by the inventor of the telephone; "The Miracle of Talking by Telephone," October, 1937, and "Miracle Men of the Telephone," March, 1947, both by F. Barrows Colton; and "New Miracles of the Telephone Age," July, 1954, by Robert L. Conly.



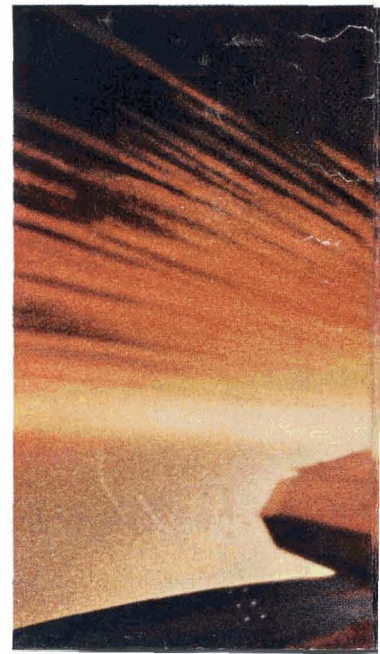
Assemblers in Immaculately Clean Gowns Build Telstar Dust-free to Assure a Long Life

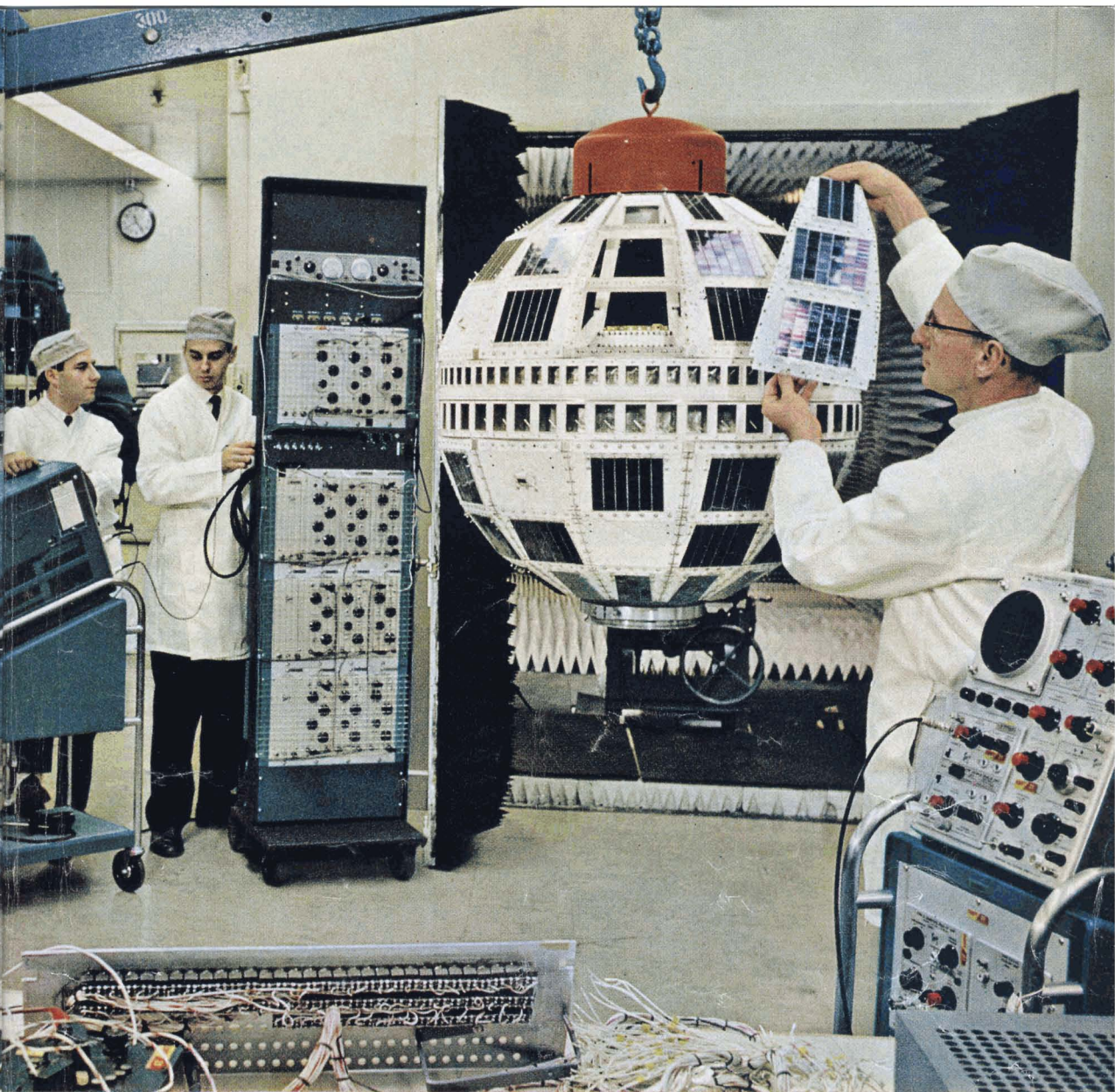
To be economically feasible, communications satellites must survive space hazards for 10 to 15 years; the experimental Telstar must live at least a year to meet design goals. Even a smudgy thumbprint on a vital part could cause contamination that would shorten life.

These men scrubbed hands, dried them on lint-free towels, and vacuum-cleaned shoes before entering the "white room" at Hillside.

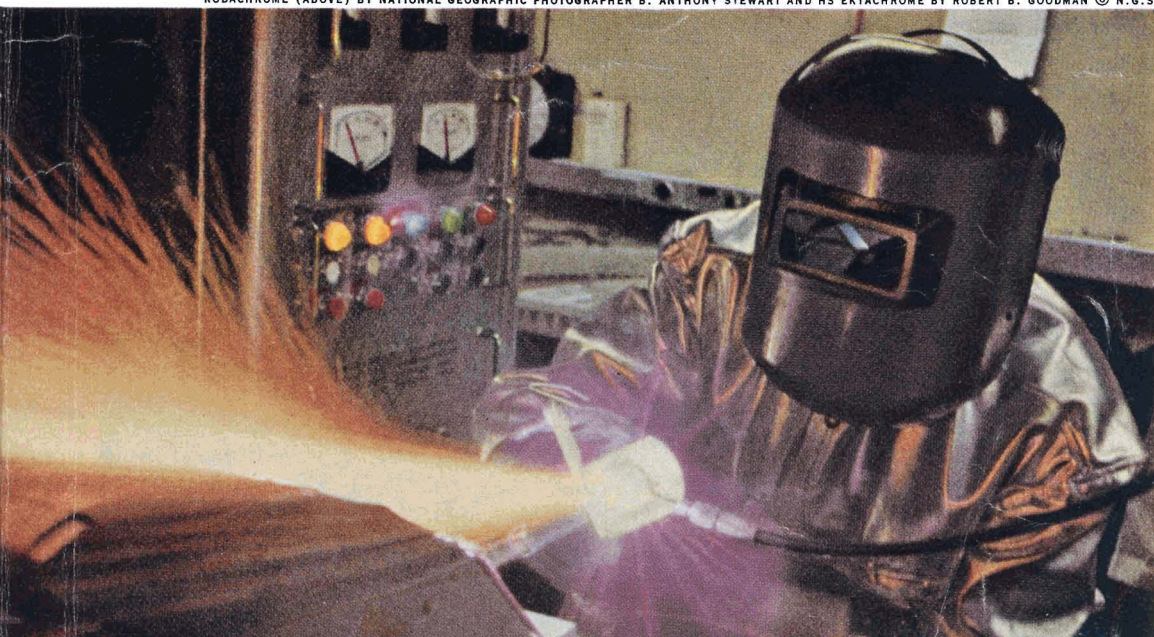
Intent worker at left checks part of the command receiver that registers instructions radioed from the ground; two others test the code generator that sends commands to the satellite. At right, a panel plated with bluish cells for tapping solar energy goes onto Telstar.

Three times as hot as the sun's surface, a flame of ionized gas bursts from a plasma jet-spray gun with the roar of a jet plane's exhaust. The intense heat melts aluminum-oxide particles and shoots them into a stream, or plasma, that sprays an outside panel of Telstar. The tough coating that results is only a tenth as thick as a human hair. Operator wears welder's hood, aluminized jacket, and earplugs for protection against glare, heat, and din.





KODACHROME (ABOVE) BY NATIONAL GEOGRAPHIC PHOTOGRAPHER B. ANTHONY STEWART AND HS EKTACHROME BY ROBERT B. GOODMAN © N.G.S.



Speed Determines Whether a Rocket Falls, Goes Into Orbit, or Escapes Into Space

The German Army's Paris Gun of World War I fired shells 76 miles into the French capital, the longest range attained in artillery's history.

Atlas, when used as an intercontinental missile, races at 16,000 miles an hour and travels as far as 6,000 miles. To launch an earth satellite, a rocket must accelerate to 17,000 miles an hour. Space probes, such as Pioneer IV, escape earth's gravity with a speed of 24,000 miles an hour.

Sir Isaac Newton in the late 17th century postulated the laws that govern trajectories and explain how a satellite stays in orbit. Simply stated: A rocket launched with too little speed falls back to earth. With too much speed, it escapes. Between the extremes lies a range of velocities at which a properly aimed object orbits earth in balance between falling and escaping, and becomes a satellite.

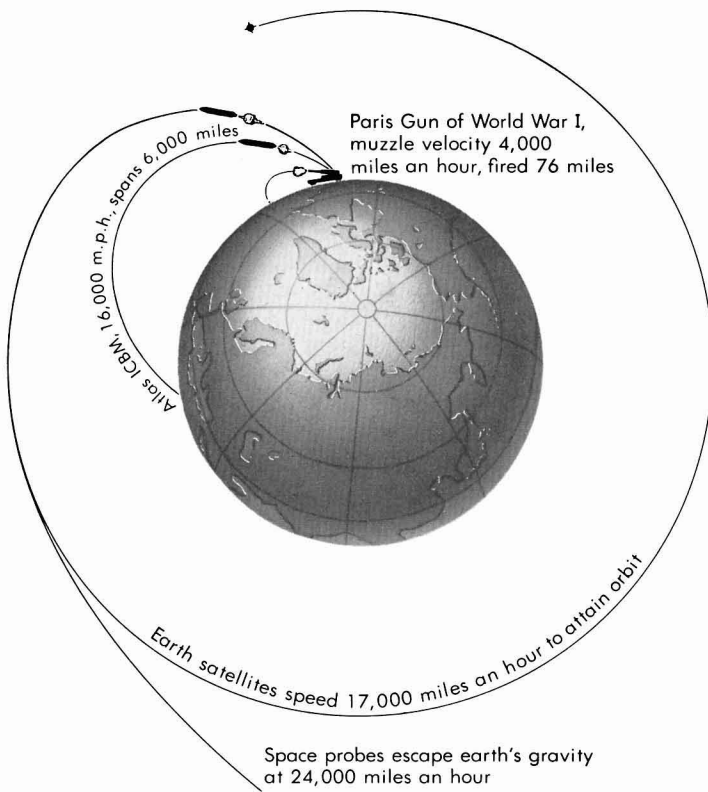


DIAGRAM BY STAFF ARTIST R. W. NICHOLSON © N.G.S.

its fellow projects. To begin with, A. T. & T., eager to pioneer in space communications, is paying its own way in both design and launching of its brain child. In addition to more than \$30,000,000 already spent on Telstar and satellite ground stations, A. T. & T. has entered a unique partnership with NASA, reimbursing the space agency for launching the satellite with a Thor-Delta rocket—some \$3,000,000. The outlays set a Space Age precedent for private investment.

Scientists Work in Dust-free Rooms

Since Telstar was scheduled to be the first of the new communicators in orbit, I had begun my tour of tomorrow's satellites at Bell's Hillside facility. There, Telstar was nearing completion.

What had looked like a hospital operating room was the fabrication laboratory for the satellite. Bell calls such laboratories "white rooms," and certainly no hospital ever took greater pains to keep out dirt and grime (page 640). Unlike hospitals, however, white rooms safeguard priceless equipment rather than people. In this case, the concern was for Telstar's delicate components, which are acutely allergic to dust.

In a white room, filters strain the air. Workers wear lint-free nylon caps and gowns, and vacuum-clean their shoes before they set foot in the laboratory. Engineers even use wash-

able crayon instead of chalk on the blackboards that inevitably stand near their conference tables.

I could have spent many hours exploring Hillside's Space Age workshop, but I wanted to learn how Telstar came to be. The place for that was the Bell Laboratories at Murray Hill, ten miles away, where the idea of Telstar was born.

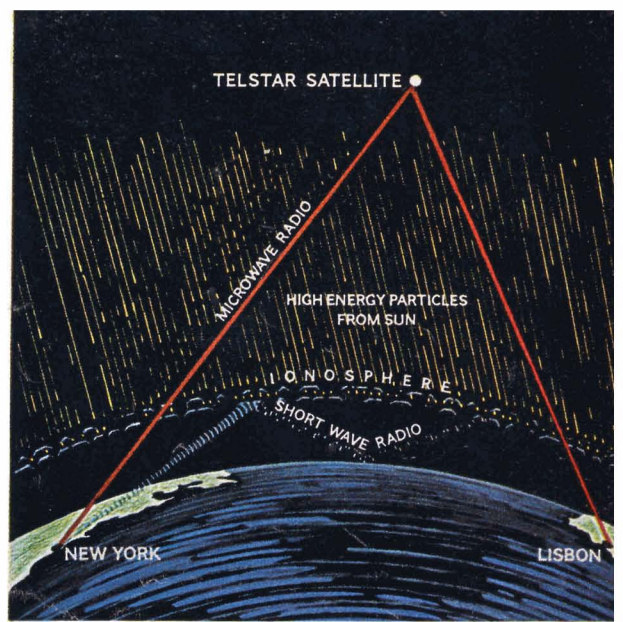
At Murray Hill, I discovered, the problems are not all in the realm of science. A big worry is simply one of time.

"In the past ten years," explained Alton C. Dickieson, director of Bell's transmission development, "the United States has seen a fantastic increase—about 75 percent—in its use of telephones. Communications carriers work night and day to keep up. We must constantly add new lines and circuits.

"But the oceans are the big barrier. The United States, for example, has only 550 telephone channels—both cable and radio—with which to handle some four million international calls a year. And in 1961 alone all transoceanic calls rose by 15 percent."

Television, he said, is another problem, for one TV signal takes up more than 600 voice channels. Though future developments may greatly expand cable capacity, the U. S. today cannot exchange by cable a single live television program with Europe.

"The challenge will increase with time,"



PAINTING BY STAFF ARTIST JOSEPH E. BARRETT © N.G.S.

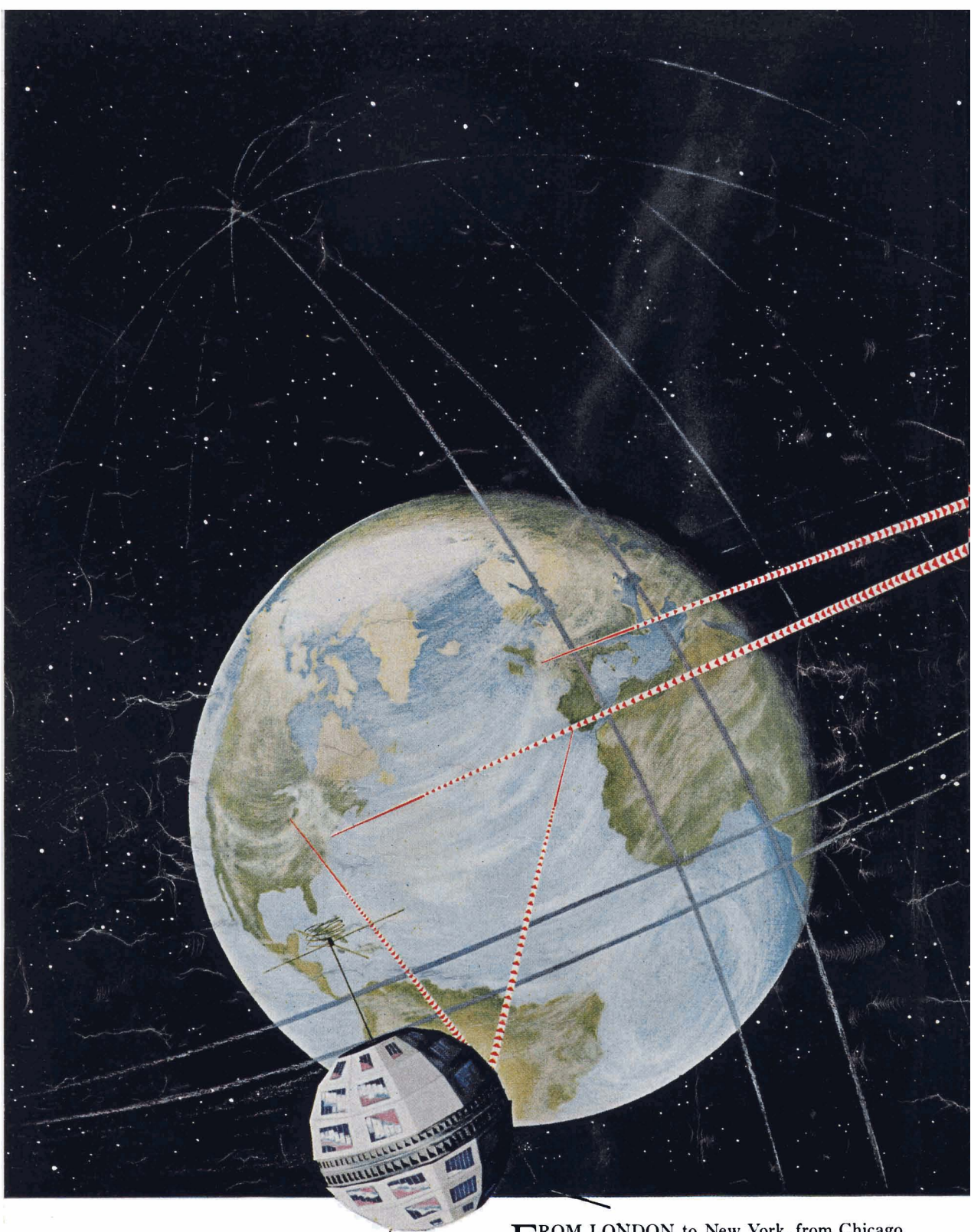
Short-wave radio signals bounce back and forth between the ionosphere and earth. But solar storms emit particles that cause the lofty reflective shield

to absorb signals, thus blocking reception. Telstar will receive and rebroadcast microwave messages that always penetrate the ionosphere.

Space Age ear trumpet, an 18-ton antenna atop Crawford Hill, near Holmdel, New Jersey, tracks and talks with satellites. Unique shape helps the Bell Laboratories' horn to receive signals as weak as the billionth of a millionth of a watt bounced to earth from the Echo I balloon satellite.

KODACHROME BY NATIONAL GEOGRAPHIC PHOTOGRAPHER B. ANTHONY STEWART © N.G.S.





Satellites at work:
relay stations
7,000 miles in space

FROM LONDON to New York, from Chicago to Lisbon, messages will leap the Atlantic via communications satellites. Painting shows how two Telstars, part of a network of scores in polar and equatorial orbits, could link distant points. Telstar at right picks up London messages on its upper belt of windowlike antennas and rebroadcasts to New York on its lower band. Satellite at left provides a similar link between Chicago and Lisbon. Mast antennas atop the Telstars and



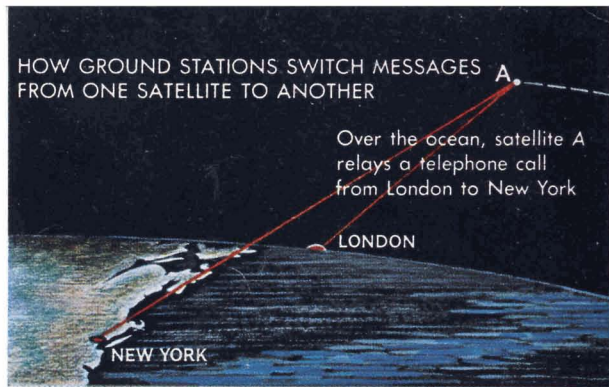
J.E. Barrett
NATIONAL GEOGRAPHIC STAFF

PAINTINGS BY STAFF ARTIST JOSEPH E. BARRETT © N.G.S.

whip antennas beneath send operational data to earth. The mast antennas also receive signals that turn the relay systems on and off during flight. Shiny solar cells change sunlight to electric power for receiver and transmitter.

Swirling gauze of clouds on the world's face follows cyclonic patterns long suspected by weathermen and recently confirmed by Tiros weather satellites.

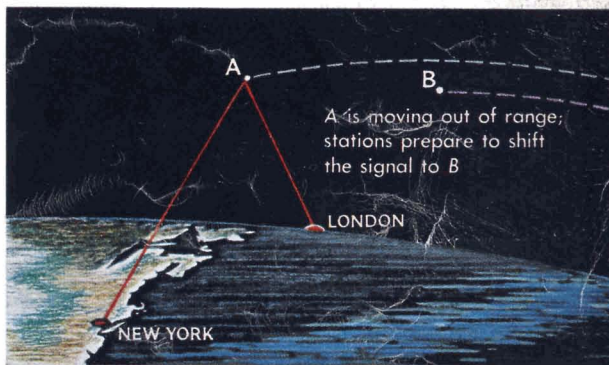
HOW GROUND STATIONS SWITCH MESSAGES FROM ONE SATELLITE TO ANOTHER



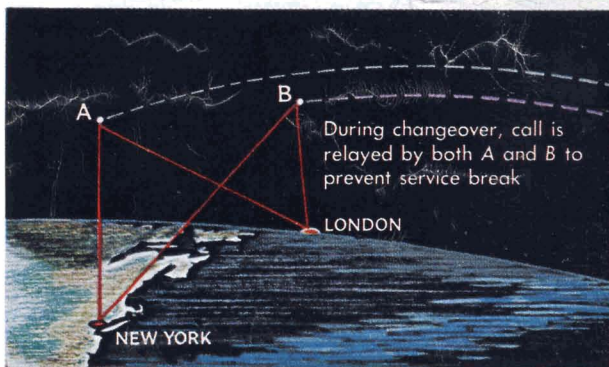
Over the ocean, satellite A relays a telephone call from London to New York



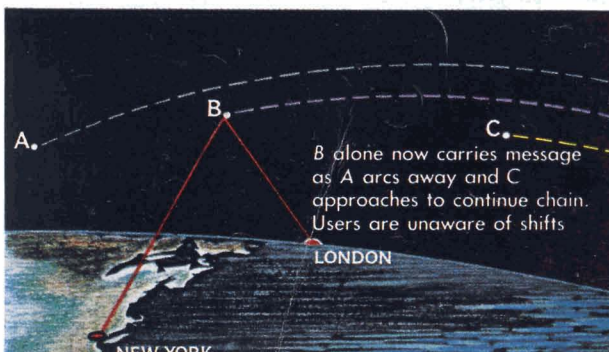
Satellite B streaks into view; A continues to handle the signal



A is moving out of range; stations prepare to shift the signal to B



During changeover, call is relayed by both A and B to prevent service break



B alone now carries message as A arcs away and C approaches to continue chain. Users are unaware of shifts



HS EKTACHROMES BY ROBERT B. GOODMAN © N.G.S.

Man-made rubies form the hearts of ground-station amplifiers called masers, which multiply weak signals from space 4,000 times. Synthetic rubies have the same structure as those found in nature. Amplifying energy comes from chromium atoms, which also make ruby red.

Kettleful of "space"—vacuum, cold, and solar heat and light—exists in a chamber that tests a part of Telstar. Plumes mark escape of the coolant, liquid nitrogen at -323°F .



Mr. Dickieson continued. "World demand for telephone service will grow even faster during the next decade. Undersea cables are expensive, and microwave relays—radio voice transmission by means of towers spaced a few miles apart—cannot be built across an ocean."

But, I asked, why turn to satellites? Can't short-wave radio, such as radio hams use, solve the problem?

"The answer is no," he replied. "For one thing, short-wave channels are already crowded. For another, short-wave radio depends on signals bounced from one point on the globe to another, using a high layer of the atmosphere as a sort of electronic mirror. The difficulty there is that solar storms—sunspots—and other magnetic disturbances can play havoc with short wave and even block it out entirely [see drawings, page 643]."

"If you've ever talked between one country and another by short-wave radiotelephone, you know the fade, static, and interruptions that can occur. The problem is to find something that will reliably relay hundreds or even thousands of conversations across the world's oceans. A satellite network can do it."

Telstar is a sun-powered space station designed to receive microwave signals beamed from earth, boost their power, and fire them back to ground strong enough to be received. To understand just how Telstar does it, I went to Dr. John R. Pierce, an executive director of research at Murray Hill, who was first to offer concrete proposals for a communications satellite.

Jeweled Windows Tap Sun's Power

Dr. Pierce is a slender, soft-spoken man with an amazing mind some have compared to a computer. He has many talents, among them a gift for writing science fiction, published under the pen name J. J. Coupling.

"No one can doubt the urgency of a communications satellite system," Dr. Pierce began. "We estimate that 20 to 25 Telstars in a web of random orbits could provide telephone and television circuits to Europe, while 30 to 50 could eventually link all the countries of the world.

"Moreover," Dr. Pierce said, "satellites using wide radio bands—the frequencies lie in the range between 1,000 and 10,000 megacycles—can handle many more telephone channels than our present cables can, and television as well. They're like superhighways compared to country roads in terms of traffic."

I had visions of sitting in my own living room near Washington, D. C., and seeing broadcasts of an opening of the British Parlia-

ment or some future Olympic Games in Asia.

To learn more about Telstar, I met Eugene F. O'Neill, Telstar project director (page 650).

I found that those little gleaming rectangles I had seen—3,600 of them on the 170-pound ball—are solar cells that convert sunlight into electrical energy (page 641).

They are expensive items, those cells. Each one is coated with hard synthetic sapphire to protect it from radiation. Telstar must live and work while orbiting through the most intense part of the radiation layer known as the Van Allen belt.

"Reliability is everything," Mr. O'Neill explained. "Once a satellite leaves the launching pad at Cape Canaveral, you can't bring it down for repairs."

I asked how high Telstar would fly.

"The first model will have an orbit of 600 to 3,500 miles altitude and circle the globe every two hours and 40 minutes," Mr. O'Neill answered. "Later we plan an orbit 6,000 to 7,000 miles in space. With 50 Telstars circling the earth, at least one of them would be within range of any two sending and receiving continents virtually all the time."

Six thousand miles meant a 12,000-mile round trip for a radio signal. I asked if the signal wouldn't lose a great deal of its power on the way.

"Yes," Mr. O'Neill admitted, "between satellite and ground receiver alone, the signal's power will drop from two-and-a-half watts to about one-trillionth of a watt."

My amazement showed. "Then how can you ever hope to pick it up?"

Gene O'Neill smiled and said: "Go take a look at the receiver."

Hearing Aid Weighs 340 Tons

Near Andover, Maine, you can see the reason for the O'Neill smile. There, in a pine-fringed clearing, A. T. & T. has built what surely is the world's largest ear trumpet. The 340-ton aluminum-and-steel antenna does just two things and does them well: With pinpoint accuracy it beams signals to satellites flying the immensity of space, and it scoops unbelievably faint radio signals from space while screening out surrounding noise. To protect the giant hearing aid, engineers have enclosed it in an inflated rubberized Dacron radome the size of a 14-story office building (page 650).

"During early tests of Telstar," Mr. O'Neill explained to me, "Andover will handle both the transmission and the reception of signals. It's no difficult trick to transmit—the real job comes in picking up the relayed signal.



KODACHROME BY ROBERT B. GOODMAN © N.G.S.

Coil glows with heat that bonds pieces of a key amplifying device held within. The amplifier, which goes inside Telstar, gives radio signals enough power to reach ground stations. Called a traveling wave tube, it causes the signal to travel in a spiral path around a stream of electrons, from which it gains energy. Protective shield shadows the viewer's face with a grid pattern.

"A big problem is extraneous noise. When a communications engineer speaks of noise, he means anything that interferes with his signal. Did you know that heat released by falling rain can make a sensitive receiver roar like Niagara Falls? You yourself produce noise just by the heat of your body."

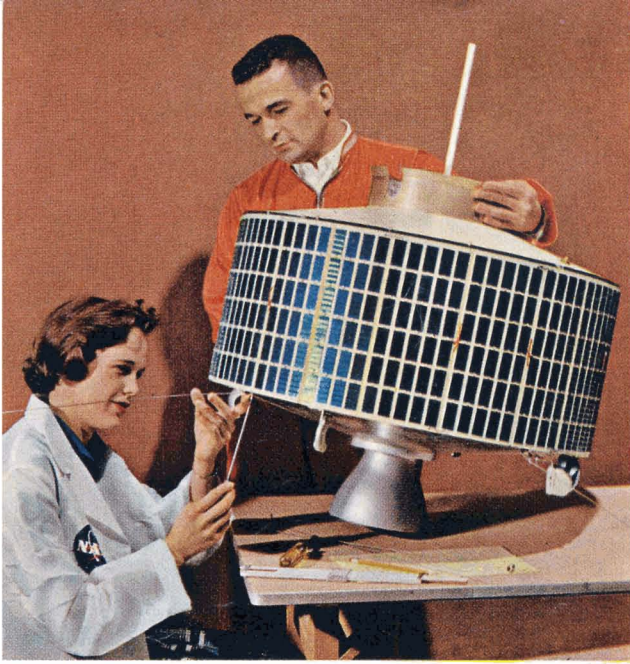
I asked what could be done about this electronic racket.

"Ten years ago," Mr. O'Neill replied, "we couldn't have strained Telstar's signal out of the mass of noise that exists everywhere. But that was before the maser."

At Murray Hill I had seen the maser (pronounced mayzer), an electronic marvel first brought to practical use at Bell Laboratories. Masers, whose hearts are synthetic rubies, amplify electrical impulses without picking up interference and without producing noise.

The word maser stands for "microwave amplification by stimulated emission of radiation." The ruby, a slender, rose-colored crystal about six inches long, operates in a bath of liquid helium at the fantastically low temperature of minus 456° Fahrenheit—nearly absolute zero.

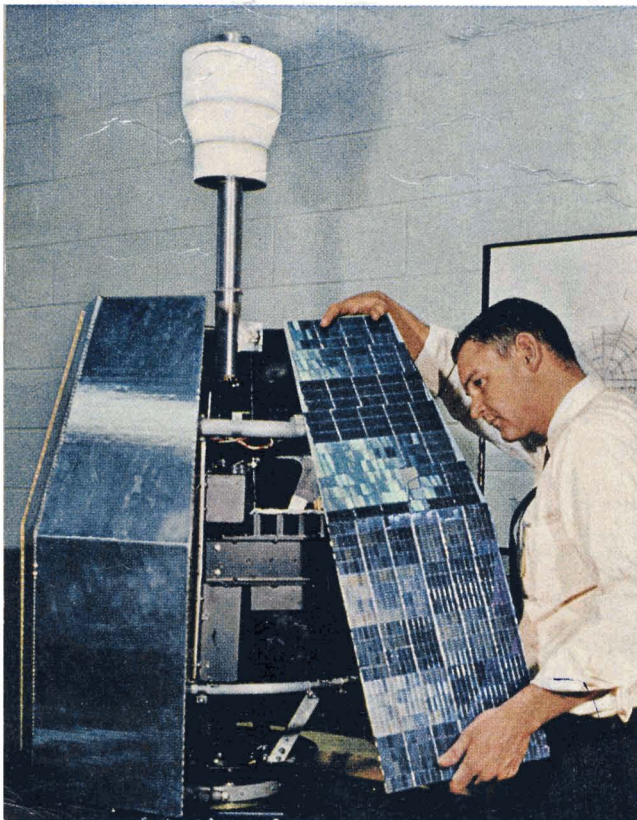
"By means of masers," Mr. O'Neill said, "our big horn here can amplify Telstar's signal about four thousand times—enough for us to pick it up."



Syncom, Hughes Aircraft's flyweight satellite, will orbit to coincide with the earth's rotation. Here it rests on the nozzle of a small built-in rocket that will give the 60-pound communicator a final kick into synchronous orbit, 22,300 miles high, after a Thor-Delta lifts it from earth. Syncom undergoes tests at the Goddard Space Flight Center, a National Aeronautics and Space Administration facility at Greenbelt, Maryland.

Relay, a low-altitude satellite for NASA, acquires a solar-cell panel at R.C.A.'s space laboratories in Princeton, New Jersey. White plastic protects the antenna during its jarring ride to space.

KODACHROMES BY NATIONAL GEOGRAPHIC PHOTOGRAPHER JOHN E. FLETCHER © N.G.S.



I learned that Andover was chosen for the ground station because of the site's remoteness from electrical interference and because of its easterly vantage point for keeping watch on satellites above the Atlantic.

When Telstar reaches its planned orbit, Mr. O'Neill's crew will make the first transmitting and receiving tests during the first passes within range of Andover.

"We'll have 20 to 45 minutes—the time Telstar will remain within our range on each pass," Mr. O'Neill explained. "But that will be enough. Our small tracking antennas will pick up Telstar quickly and put the main antenna on target.

"Then we'll put a test signal on the transmitter, followed by several telephone messages. Next we'll try a television signal. If we get a good picture on our TV monitor screens in the control room, we'll know Telstar is a complete success."

Later, Telstar's signals will be picked up by the Bell Laboratories receiving site near Holmdel, New Jersey (page 643), and still later by stations in Europe. France is building a station at Lannion in Brittany, and Britain is constructing another at Goonhilly Downs in Cornwall. With each new test, the day of space-borne telephone and television will be a little closer.

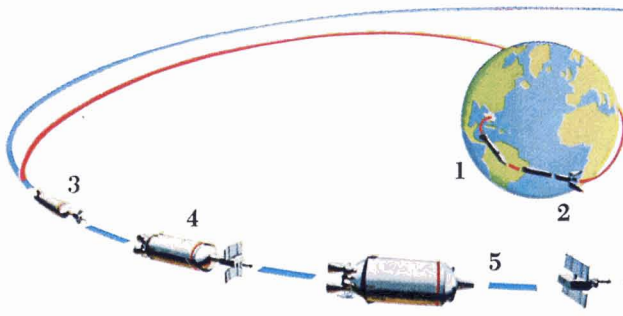
Telstar is scheduled to be first in orbit, but it will be only one of several satellites now being built for the same purpose. I saw another, the Radio Corporation of America's Relay, under construction at Princeton, New Jersey (lower left).

Though Relay looks different and weighs less (130 pounds total), it resembles Telstar in many ways. Both are pilot models for what may eventually be scores of satellites, all circling the earth in a few hours and handling traffic in turn as they pass the sending and receiving countries (see diagrams, page 645). Relay's launching date: late summer.

Syncom: Star That Never Sets

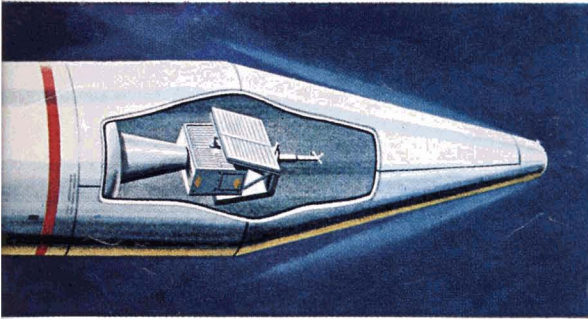
A quite different kind of communications satellite is nearing completion in Culver City, California. While Telstar streaks across the sky, this one, called Syncom (upper left), will hang perpetually in one spot—or so it will seem to us on earth. Actually, if Syncom reaches its ideal speed—6,800 miles an hour—and altitude—22,300 miles—it will exactly pace the earth's rotation. In other words, it will be synchronized; hence its name.

A fantastic idea, perhaps, but the men building Syncom are hopeful it can be done. They

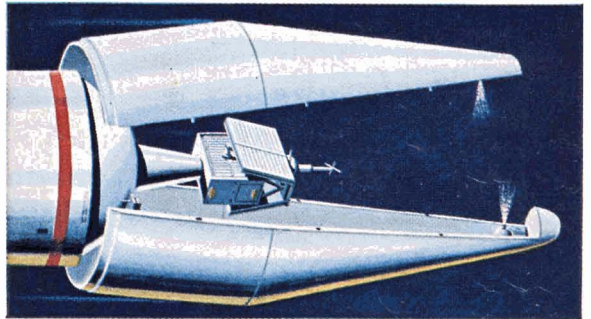


Advent, the Defense Department's satellite, ascends to its station in space along a widening spiral path. The box-shaped space vehicle promises a reliable system of global communications for the Nation's military forces.

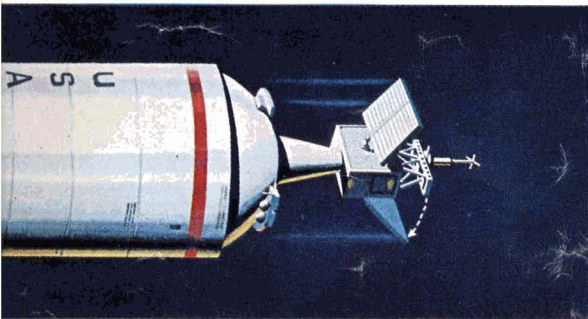
HOW A SATELLITE UNFOLDS IN SPACE



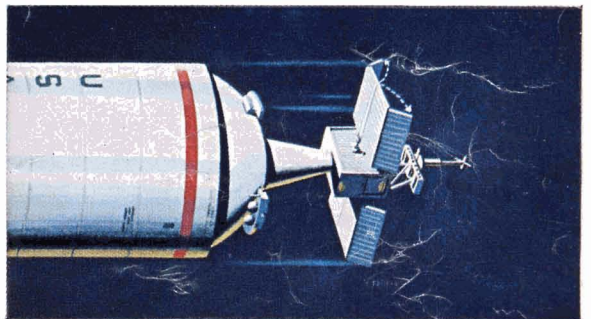
1. Fiberglass shroud shields Advent from air friction



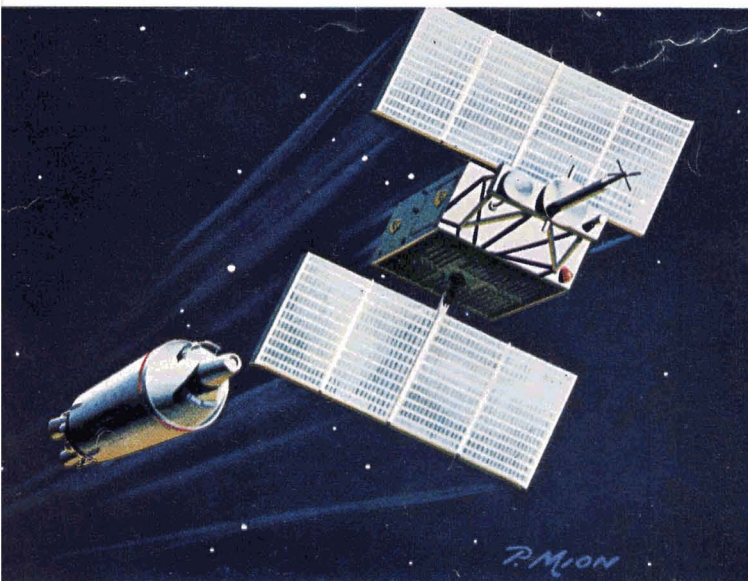
2. In space, the shroud parts, exposing satellite



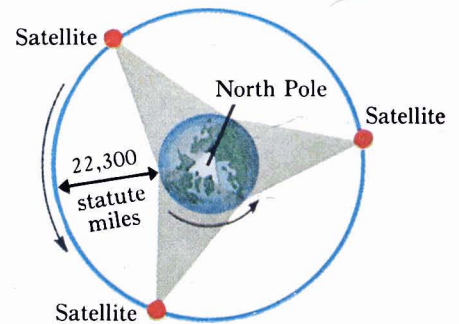
3. No friction tugs as solar paddles extend



4. Paddles unfolding, Advent coasts in orbit

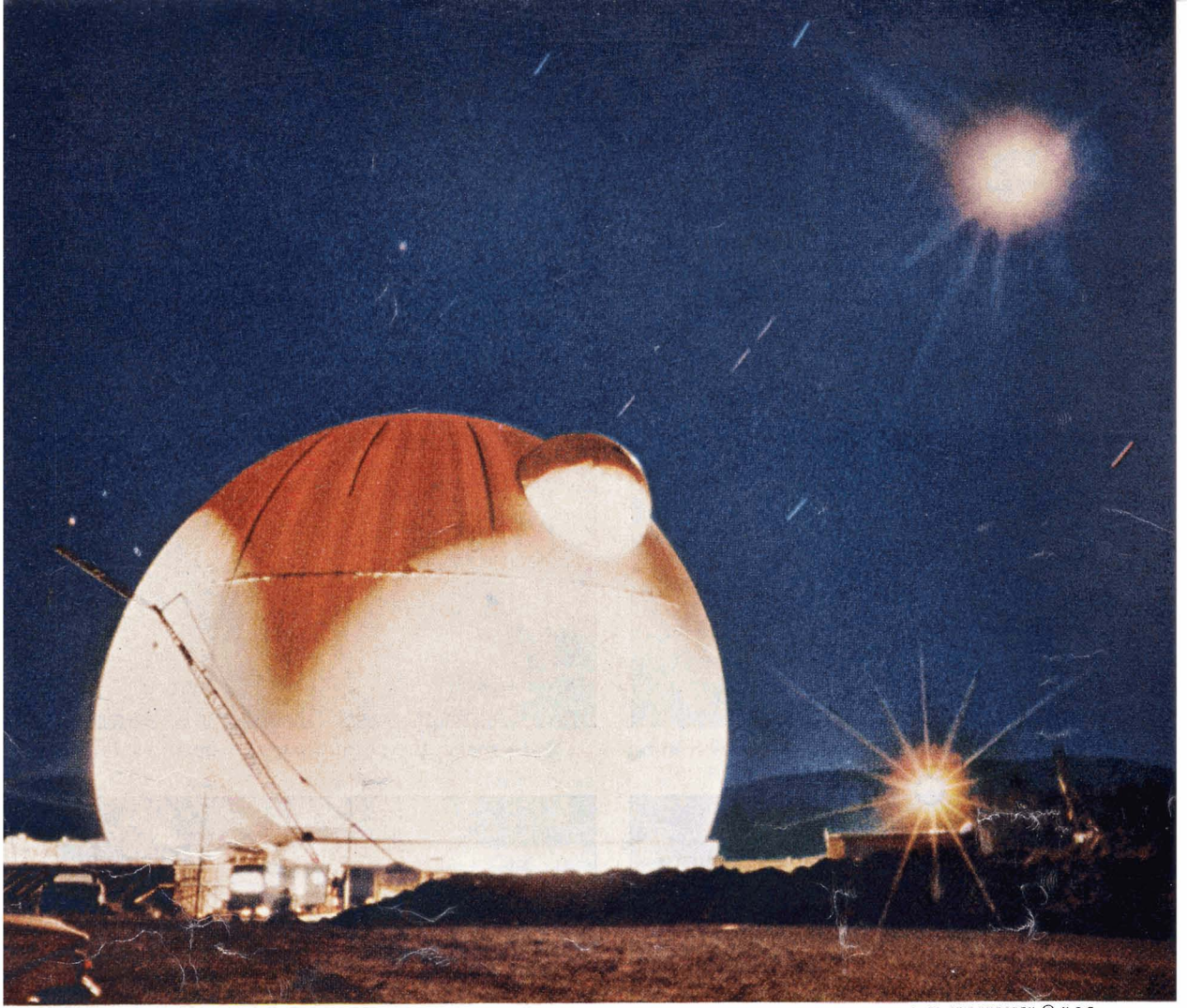


5. Explosive bolts free satellite; the 9-foot paddles, holding 38,400 silicon cells, convert solar energy into electricity



Three Advents Can Relay Signals to Any Point but the Polar Areas

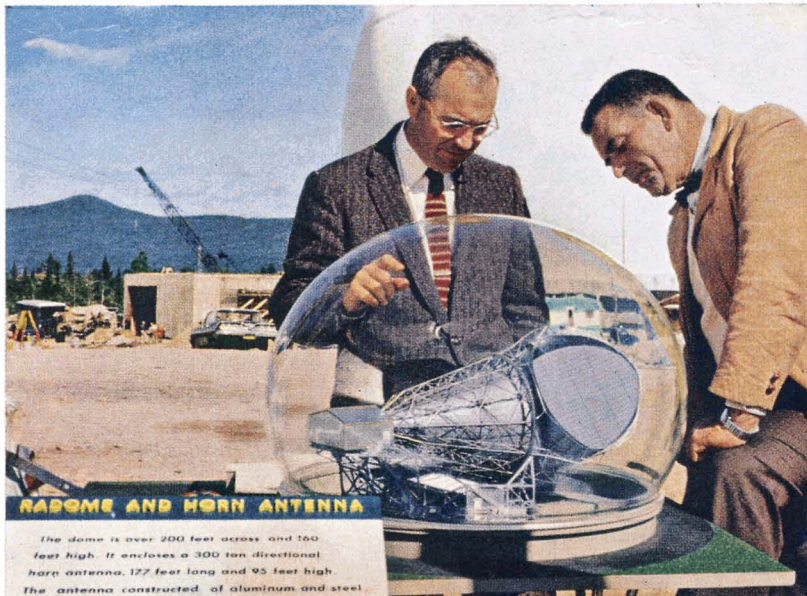
As if locked to the earth's turning, Advent will orbit once each 24 hours, its speed exactly matching the planet's rotation. Sun-powered flywheels turn the satellite so that its message-gathering antennas, like the moon's familiar face, constantly look to the globe.



HS EKTACHROME (ABOVE) AND KODACHROME BY NATIONAL GEOGRAPHIC PHOTOGRAPHER OTIS IMBODEN © N.G.S.

Bubble of fabric, supported by air pressure, protects the world's biggest horn antenna at Andover, near Rumford, Maine. American Telephone and Telegraph Company built the 340-ton trumpet to converse with Telstar and Relay satellites. Seen under a full moon, the 160-foot-high dome shields the horn during construction. A rubberized Dacron cover has since replaced the temporary nylon shown here. Time exposure makes the stars in this photograph appear as diagonal streaks of light.

650



Model horn engrosses Eugene F. O'Neill (left), Telstar project director for Bell Laboratories, and Burdick W. Pierce, an A. T. & T. senior engineer. The model's dome, unlike the actual one, is transparent.

Dome prevents warping by wind and weather, which would distort the horn's tracking eye.

Turning with ballet-dancer grace, the huge horn has an error margin of less than 1/20 of a degree of arc. It rests on a mass of concrete — 4,000 cubic yards.

RAMOME AND HORN ANTENNA

The dome is over 200 feet across and 160 feet high. It encloses a 300-ton directional horn antenna, 177 feet long and 95 feet high. The antenna constructed of aluminum and steel.

Man appears fly-size as he inspects the temporary dome for leaks. During inflation a squall almost blew the loose nylon away; once filled, the bubble defied gales. During deflation smaller bulge covers the horn's cab and its sensitive instruments.

are scientists at the Aerospace Division of Hughes Aircraft Company. The Thor-Delta rocket bearing their 60-pound satellite is scheduled to roar into space next spring.

"The beauty of Syncom," project manager Gordon Murphy told me, "is that only three would cover the world. In effect they would hang 'motionless' above the Equator. Using one—and in some cases two—of the three Syncoms, any point on earth except for the polar regions could send messages to any other."

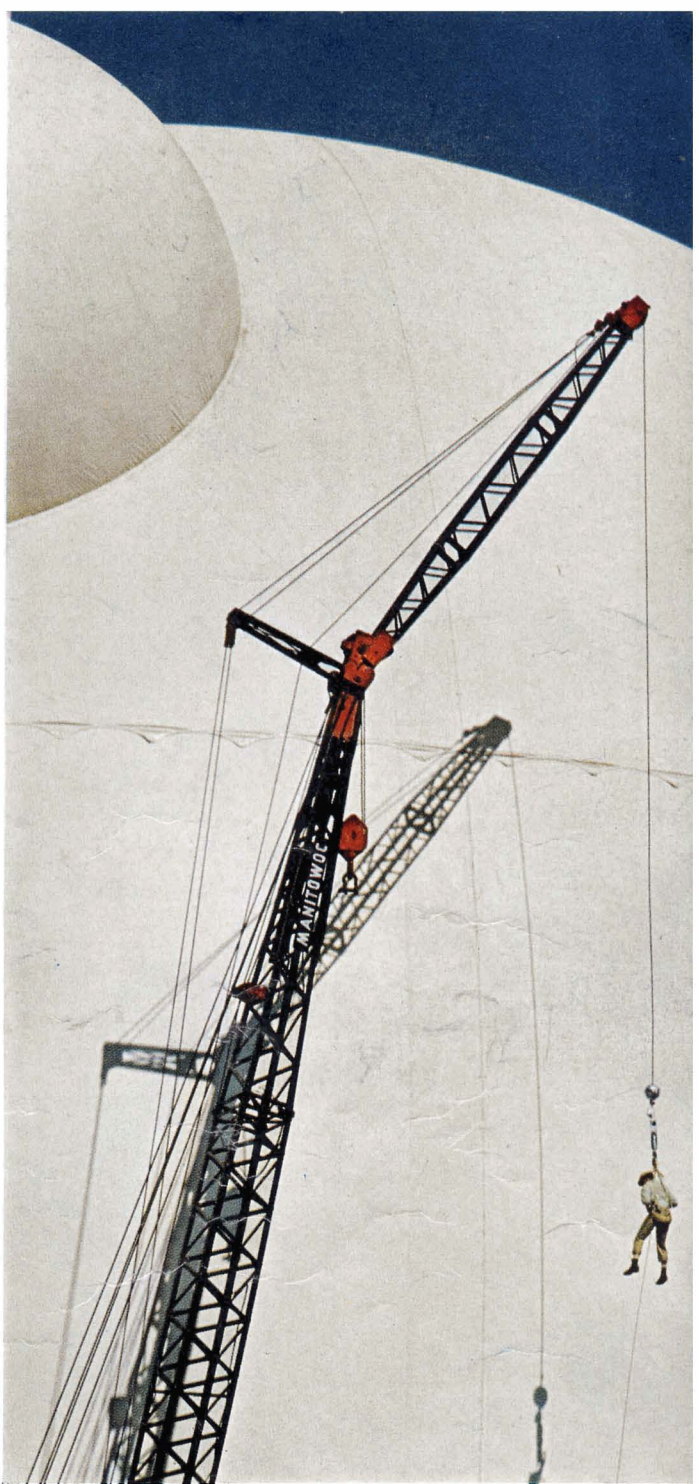
Space Age "Birds" Serve Man

Next day I stood beside what looked like a footlocker that had grown paddles. It was Advent, a synchronous satellite that General Electric and Bendix built for the Army.

Brig. Gen. William M. Thames, then commanding the Advent Management Agency at Fort Monmouth, New Jersey, explained why Advent weighs several hundred pounds, much more than its commercial cousins, such as Telstar.

"Our ground stations must be flexible," he said. "They need mobility to go into remote, possibly hostile areas. This means smaller antennas. Advent must make up the difference with more solar cells, circuits, and attitude controls. It all adds up to more weight."

Advent's weight requires a powerful rocket, and the satellite may wait a year before the hydrogen-fueled Centaur is ready to lift it to a 24-hour, synchronous orbit. Even with Centaur, Advent must climb to its 22,300-mile-high post by phases. First, it attains a 100-mile-high orbit clear of the atmosphere. Next, upper stages fire it into a far-looping transfer orbit. Finally, a burst of flame at the top of the transfer orbit hurls it into a circular path over the Equator (page 649). An early model Advent is due to fly this year at lower altitude—5,000 to 6,000 miles.



KODACHROME © NATIONAL GEOGRAPHIC SOCIETY

As I left Fort Monmouth, I saw a curious and moving sight in an era of space communications. It was a homing pigeon in bronze, GI Joe, the bird that saved advancing troops from bombing by friendly planes in World War II. The memorial honored all the homing pigeons that had served the Nation, birds with such famous names as Spike and Cher Ami. Now other "birds" replace them—electronic miracles with names like Advent, Syncom, Relay, and Telstar.