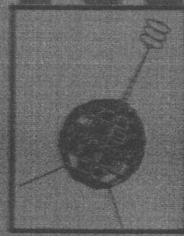
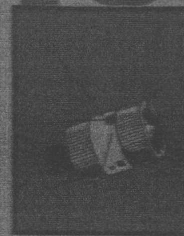
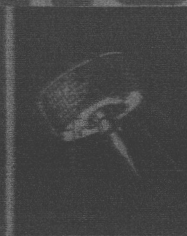
COMMUNICATIONS SATELLITES

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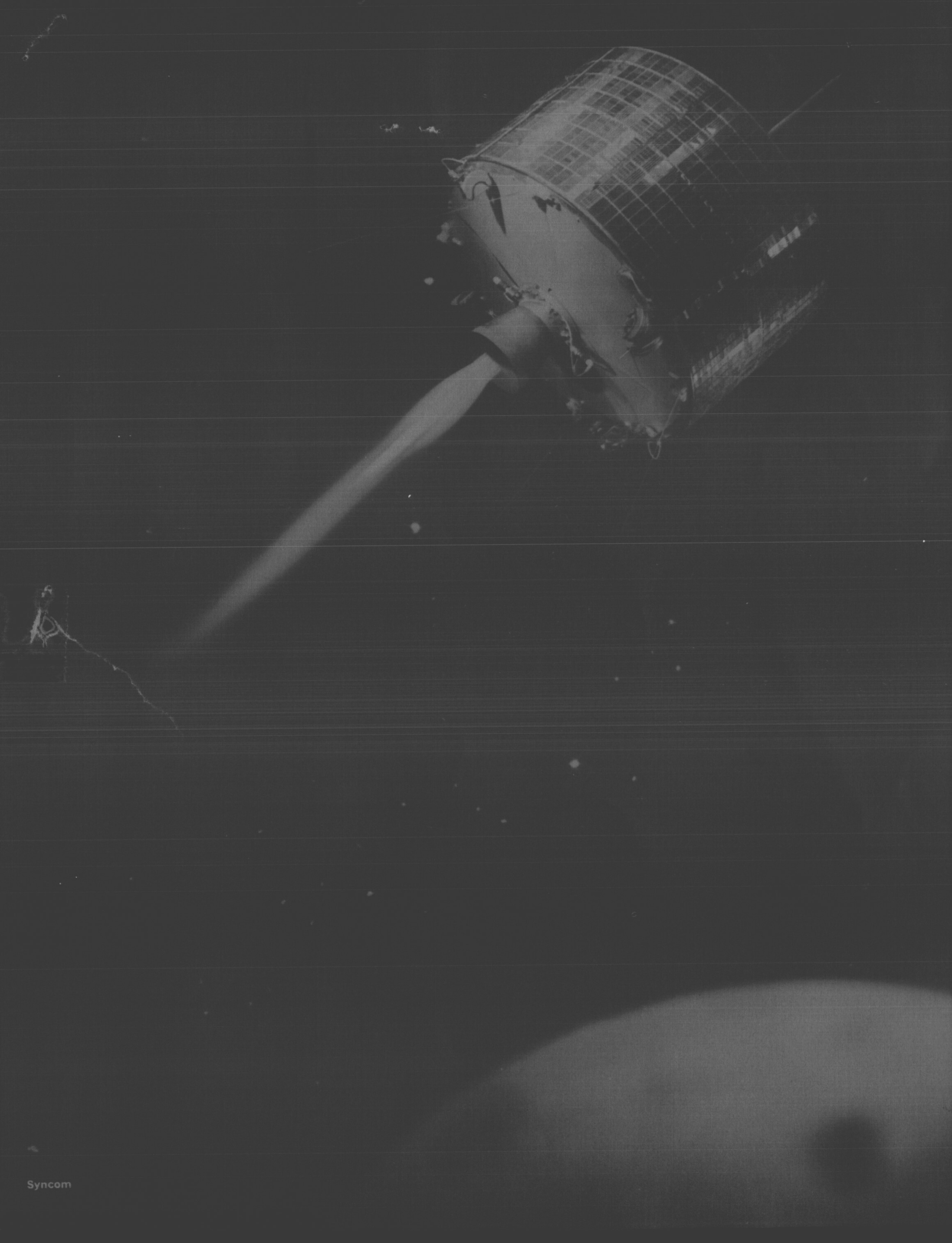


Syncom

COMMUNICATIONS SATELLITES

THE COVER—The satellites at top, left to right: Telstar, Applications Technology Satellite, Syncom. Lower right: Relay.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

2

Introduction

With the birth of the space age, the United States immediately set to the challenge of bending the great promise of space to the world's growing need for communications. In 1958, the National Aeronautics and Space Administration initiated an experimental program to develop the technology for an artificial communications satellite and make that technology available to the designers of operational systems.

Seven years later, the first phase of NASA's vigorous program was completed, and the fruit of its effort could be seen in the plans of a consortium of 20 nations, together with the U.S. Communications Satellite Corp., to establish an international operational system.

This is a report of what happened during those 7 years, of the historical elements which shaped them, and of the future which they in turn have helped to mold.

Historical Background

Civilization has always been dependent on communication—the transmission of information and ideas between individuals and between groups. But until a century ago, men concerned themselves primarily with the content of communication: they explored the implications of the ideas that stirred them; they developed the tools—the words and the images and the sounds, and the physical tools, too, the stylus and then the printing press—which raised the act of communicating to among the most exalted, necessary and meaningful of human adventures. But the *means* of communication changed very little over the centuries: the visual signal was effective as far as the eye could see, the spoken word—or the shouted warning—as far as the voice could reach; and the message, oral or recorded, could travel only as fast and as far as the courier who was carrying it.

The absence of communications capable of keeping pace with history was keenly and often tragically felt: men died at the Battle of New Orleans, the last engagement of the War of 1812, unaware that the Treaty of Ghent, which ended the conflict, had been signed 2 weeks before.

A century ago, dramatic changes began to occur. Man was launched then on the incredible adventure which would transform his world and alter the structure of his society: the accelerated acquisition of scientific knowledge, and the application of that knowledge—through technological advances—to the forces of nature.

The breakthrough which first catapulted communications beyond its line-of-sight and range-of-sound limitations was Samuel Morse's development of the technique of transmitting signals by electrical impulse along a length of conducting wire. His electromagnetic telegraph became the first commercial application of electricity.

Voice transmission broke out of that same confinement a few decades later with Alexander Graham Bell's invention of the telephone in 1876.

With the telephone and the telegraph, man's ability to communicate rapidly over distance was limited only by his capacity for stringing wire and cable. But already men of the new technology were experimenting with a force which would permit communications to leap even this barrier: electromagnetic wave radiation. It was reasoned that if this radiation could be controlled and regulated, it could provide fast communications not requiring wire or cables.

Guglielmo Marconi discovered a practical way to accomplish this, and in 1896 the first wireless radio communication was completed.

Hard on the heels of their development, these devices were put to the task of bridging the oceans and linking the continents. Twenty-two years after Morse proved that telegraphy was workable, President Buchanan and Queen Victoria exchanged messages over the first transatlantic telegraph cable. Marconi sent signals with his wireless radio across the English Channel in 1898, and across the Atlantic in 1901. The human voice spanned the seas in 1915, when the Bell Telephone System, with the help of the U.S. Navy, made a radio telephone hookup linking Honolulu, Washington, and Paris.

The effect of these technological triumphs and their subsequent commercial development was to link the civilized world in a single community for the first time.

4

Passive and Active Satellites

The moon had served as what is called a passive communications satellite—one which simply acts as a radio mirror, reflecting the signals transmitted by one ground station to the receiver of another.

The passive satellite is one of two basic types possible. The other kind—the active satellite—amplifies and retransmits the signals it intercepts.

Of the two, the passive satellite is simpler and potentially more reliable, for it has no working parts, no electronics which can fail. However, since it can only reflect signals, it requires extremely powerful transmitters and sensitive receivers on the ground.

NASA's program was designed to include development of both types of satellites.

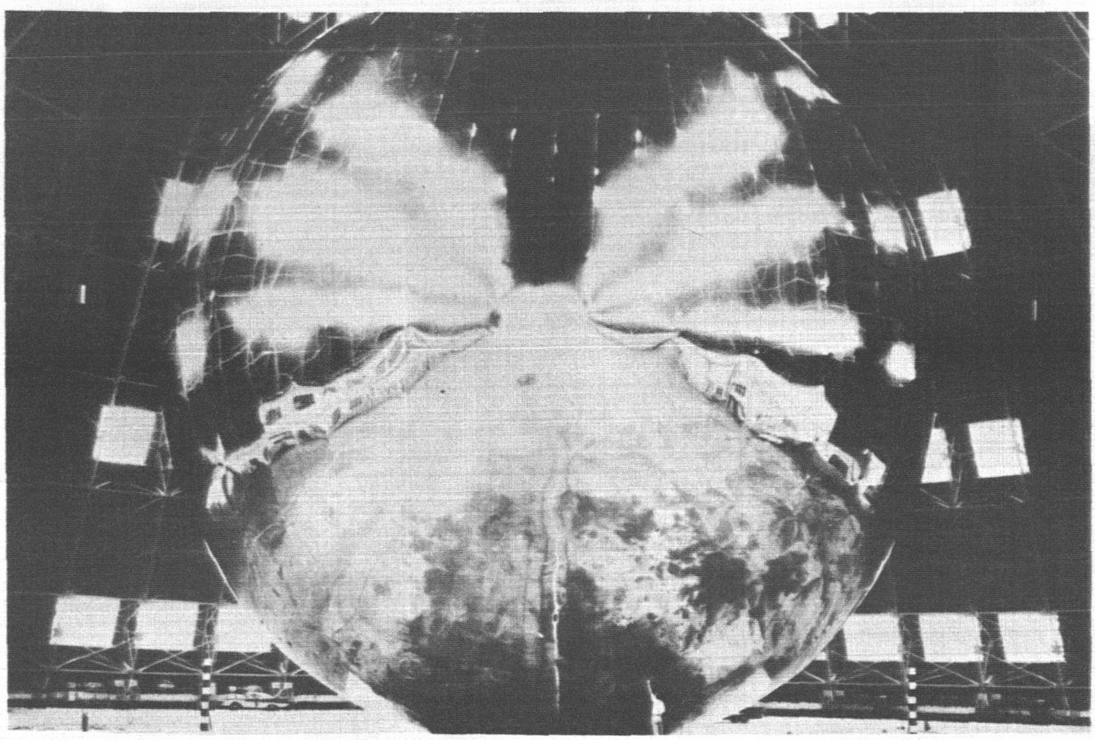
Echo I

NASA's first experimental communications satellite, Echo I, was a passive one. It was launched into orbit August 12, 1960. A metalized balloon, made of aluminum-coated mylar polyester plastic approximately 500-millionths of an inch thick (about half the thickness of the cellophane on a package of cigarettes), Echo I left earth folded inside a canister 26 inches in diameter. It was launched into space by a Delta rocket.

Once in its 1,000-mile-high orbit, Echo I was ejected from its canister and a special material inside it changed from solid state to gas, expanding the folded balloon to a sphere 100 feet in diameter and weighing 124 pounds.

Echo I has also been called the symbol of NASA's research efforts. Readily visible to the unaided eye, it has been seen by and has fired the imagination of millions around the globe. Newspapers throughout the

Echo I was NASA's first passive satellite.



The Need

But even these striking developments were hardly enough. History was moving fast. In a world expanding rapidly in populations and new nations and international commerce, the need for adequate communications threatened to outpace accomplishment. What else, besides telephone cable, offered hope?

Ever since Marconi, low-frequency longwaves which can propagate signals that follow the curvature of the earth had been used for telegraphy, and still are widely used today. But they offered no real solution to the expanding needs of the future: they are limited in the amount of telegraphic information they can carry, and they cannot be used at all for voice or television transmission.

Nor was shortwave radio the answer. It is a useful medium for voice communications, but its vulnerability to weather and ionospheric disturbances affects its reliability.

The Solution

By the 1950's, one medium was recognized as being ideally suited to carrying vast quantities of every known form of communication, immune to disturbance: the extremely short, ultrahigh frequency radio signals known as *microwaves*.

But there was a problem: microwaves, like light, travel in a straight line, and thus are limited to line of sight.

Over land, this limitation has been overcome by the use of repeater systems: antennas mounted on towers spaced 20 to 30 miles apart, which relay the microwaves in a straight line from point to point. Obviously, however, such a system offers no solution for transoceanic communications. (The 20–30 mile interval between towers can be extended by increasing the height of the towers; but a single tower, even if it could be constructed in the middle of the Atlantic Ocean to link the United States and Europe, would have to be more than 400 miles high.)

But there was a solution, or at least the promise of one, and it came with the knowledge that man would be able to orbit artificial satellites around the earth. For a microwave repeater placed in a satellite thousands of miles above the earth would be able to span whole continents and oceans.

Moon Contact

When NASA's program to develop the technology for a communications satellite began in 1958, a form of *earth-space communications had already been effected*: in 1946, the U.S. Army Signal Corps made radar contact with the moon, and subsequently conversation was possible between Washington and Hawaii by reflecting signals off the moon's surface. The moon thus actually served as a communications satellite—although its extremely high altitude and slow orbit of the earth made it an impractical one for regular communications.

The full moon; age 14 days. Radio signals have been reflected from the moon and received on earth, using it as a passive communications satellite.

United States and in many other countries ran schedules giving its orbital information after it was launched.

Echo I's public notice and acclaim were exceeded only by its scientific usefulness. It proved conclusively the feasibility of using manmade passive communications satellites. Its aluminum-coated surface reflected about 98 percent of the radio waves transmitted to it, up to frequencies of 10,000 megacycles. Those signals reflected from it made possible long distance telephone conversation, and the transmission of photographs and music.

Echo II

Using information gained from the Echo I project, NASA scientists developed Echo II, a larger and more durable passive satellite. On January 25, 1964, Echo II was placed in orbit by a 76-foot, liquid-fueled Thor-Agena rocket which developed 170,000 pounds of thrust.

When fully inflated, Echo II is 135 feet in diameter and weighs about 575 pounds. Its skin is mylar plastic bonded on both sides to aluminum alloy foil, and is some 40 percent thicker than that of Echo I.

NASA's scientists determined from their experience with Echo I that a slight initial overpressurization of the balloon would improve its surface smoothness and sphericity and thus greatly enhance its performance as a communications satellite. To achieve this they developed a controlled inflation system.

A number of packets containing pyrazole were sealed closed with temperature sensitive wax and attached to the inside of the balloon prior to folding and packing in the canister for launch. After launch and canister opening, the sphere was initially inflated with only residual air, which, as the television camera aboard the orbiting launch vehicle showed, carried the balloon to full extension in 20 seconds, but did not pressurize it. As the sphere absorbed heat from the sun, the wax seals on the pyrazole packets melted and the chemical was transformed into a gas which pressurized the balloon. This pressurization gave the skin a permanent set or stress which overcame its tendency to resume its earlier folded, wrinkled shape. Echo II has remained

Echo I as photographed by the Boston University Telescope in a time exposure. The long streak represents the satellite.

6

unchanged since its first day in orbit and is now circling the earth once every 109 minutes as it is expected to do for several years to come.

The Echo program, now complete, accomplished the following objectives:

Developed and demonstrated a long-lived, rigid sphere applicable to passive communications use;

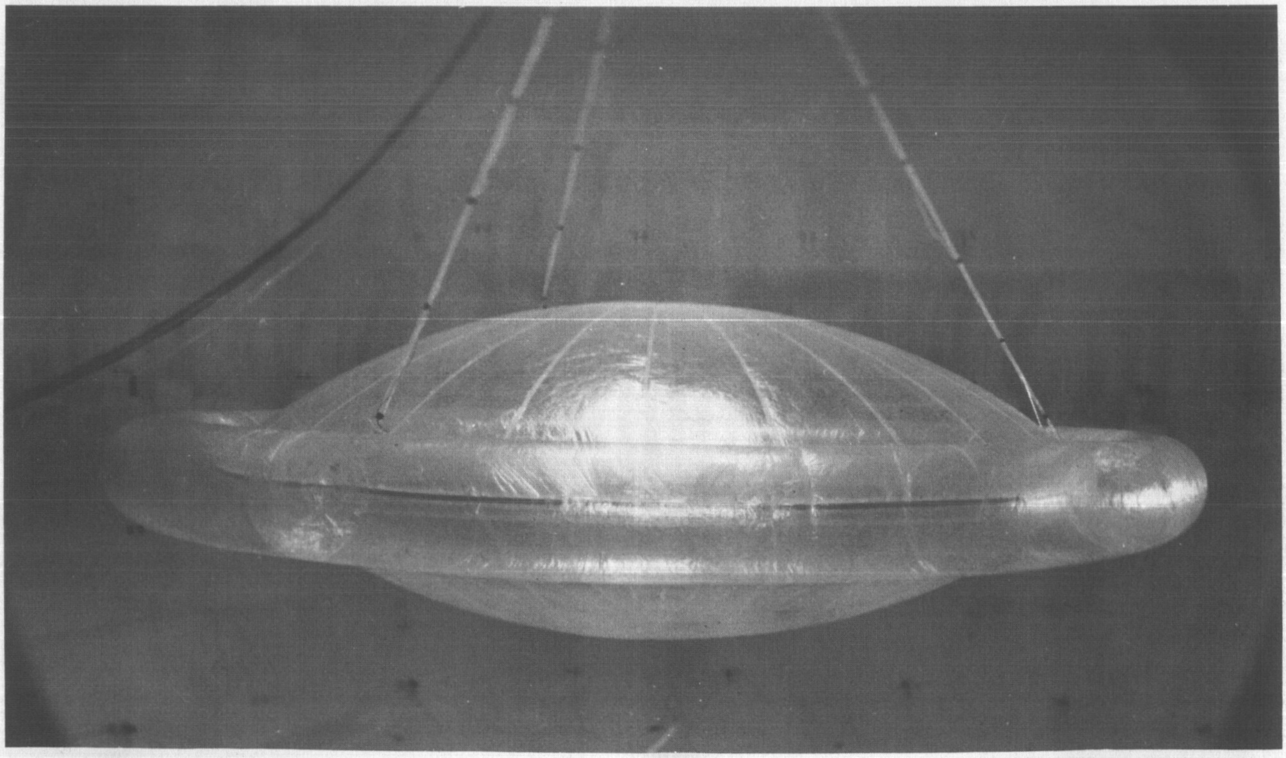
Developed improved ground test techniques for measuring the radio reflectivity of these structures;

Developed a controlled inflation system;

Developed a TV system for observing the inflation of these structures.

Echo II provided the United States with an opportunity to engage in a program of scientific cooperation with the U.S.S.R. Implementing an agreement reached in 1962, the program involved optical observations of the satellite by stations in the U.S.S.R. during its early orbits when it was not in view of any of our own tracking stations. The agreement also provided for the performance of a series of communications experiments between the Jodrell Bank Radio Observatory of the University of Manchester, operating on NASA's behalf, and the Zimenki Observatory of the Gorki State University, northeast of Moscow.

The completion of the Echo II program brought to an end flight experiments with passive satellites. NASA is continuing, however, with a small laboratory program to improve the characteristics of such satellites through the development of new construction materials and techniques as well as more efficient shapes and controls for passive satellites.



A lens shape is one possibility if passive communications satellites should be used in the future. This model was developed, and tested in a vacuum sphere, at NASA's Langley Research Center.

Active Communications Satellites

An active communications satellite amplifies the signal it receives from one ground station and retransmits it to another. Since it is itself a station in the sky, it is considerably more complicated than the mirror-like passive satellite. This is balanced, however, by the fact that much simpler equipment is required on the ground stations which work in conjunction with it.

The era of active communications satellites began in December 1958, when an Atlas rocket launched a U.S. Army relay satellite called Score into orbit.

Score carried a radio transmitter and prerecorded Christmas greetings from President Eisenhower; ground commands triggered transmission of the message.

Score was relatively short lived—approximately 30 days—but during that time it dramatically demonstrated its ability to relay voice, code, and teletype messages.

Courier, developed by the Army Signal Corps, followed on October 4, 1960, when it was launched into a 500–600-mile-high orbit.

A 500-pound sphere, measuring 51 inches in diameter, and powered by 20,000 solar cells, Courier carried 4 receivers, 4 transmitters, and 5 tape recorders.

Its purpose was to demonstrate the use of an active repeater for both real time* and delayed transmission of messages. In operation, it received signals and stored them on tape while it was in view of one ground station; then on command it retransmitted the signals when it was in sight of another station.

Technical difficulties ended Courier's ability to send messages after 18 days in orbit—but during that time it received and retransmitted 118 million words.

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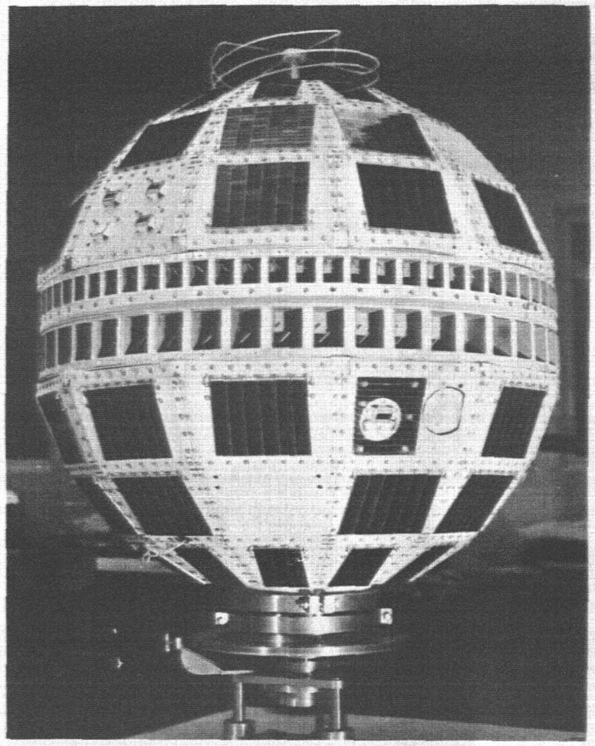
*Real time transmission is the reporting of information simultaneously with the acquisition of that information.



Telstar was developed by the American Telephone & Telegraph, launched for A. T. & T. by NASA.

Telstar

Project Telstar was developed by the American Telephone & Telegraph Co., in cooperation with NASA.

The first of the two satellites in this project—Telstar I—was launched by NASA on July 10, 1962. It was placed in orbit by a three-stage Delta rocket.

It advanced considerably the active repeater concept, and its impact on the public's attention was substantial. United States and European television stations exchanged some 50 television programs—both black and white and color; telephone calls were made in both directions, and facsimile and telephotos were relayed.

In addition, the satellite performed more than 300 valuable technical tests, almost all of them with successful results.

During the first Telstar experiments the satellite was tracked by ground stations in Maine, England, and France. Evidence of the communications satellite's contribution to international cooperation was the establishment of other ground stations in Italy, Brazil, Germany, Japan, Sweden, and Spain by late 1964.

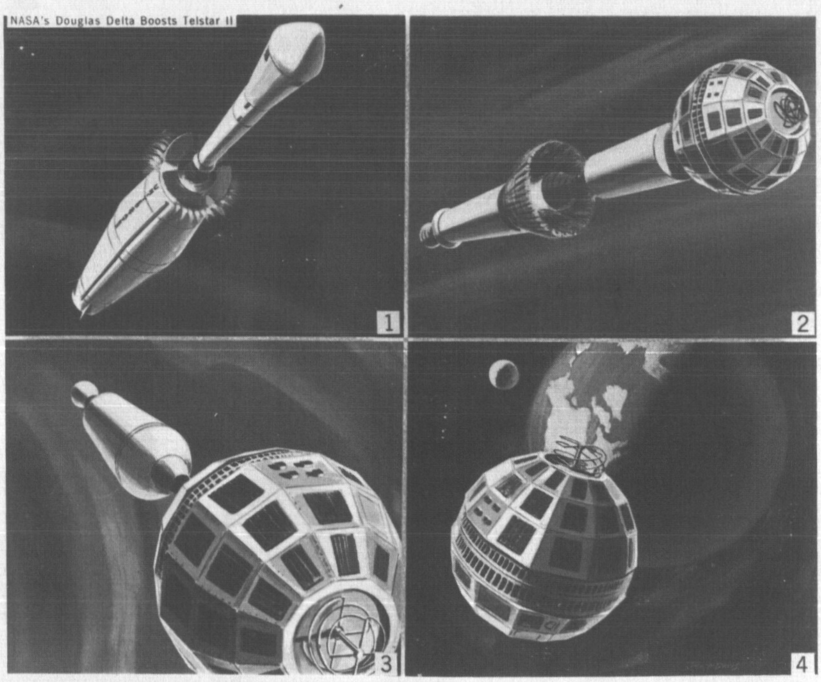
For 4 months Telstar I functioned as planned, handling more than 400 transmissions. In November 1962 the satellite unexpectedly provided U.S. scientists with another ''first''—ground diagnosis of a malfunctioning communications satellite. It was determined that unexpectedly high levels of radiation had damaged some of the transistors in the satellite's command circuit.

On February 21, 1963, after failing to respond to commands from the ground, Telstar I went silent.

Telstar II, which followed its predecessor into orbit aboard another Delta rocket 10 months later (on May 7, 1963), was much the same as Telstar I, except for a few improvements that made its weight 5 pounds heavier. A redesign of some of the second Telstar's electronics provided it with greater resistance to radiation change, and its elliptical orbit has an apogee (the farthest distance from the earth reached in the orbit) almost twice as high as that of Telstar I.

This higher altitude keeps the satellite out of the high-radiation regions of space for a greater part of the 225-minute orbiting time, and also provides it with longer periods when it is visible from, and consequently can communicate with, both United States and European ground stations.

The satellite was mysteriously silent from July 17 to August 12, 1963, but with that exception it has functioned well.



NASA-DOUGLAS DELTA FLIGHT SEQUENCE FOR TELSTAR II—Figure I shows separation of first stage. Figure 2 shows second stage separating from third stage with attached Telstar payload. Figure 3 reveals separation of Telstar II from third stage. In figure 4, Telstar II is in orbit around the earth.