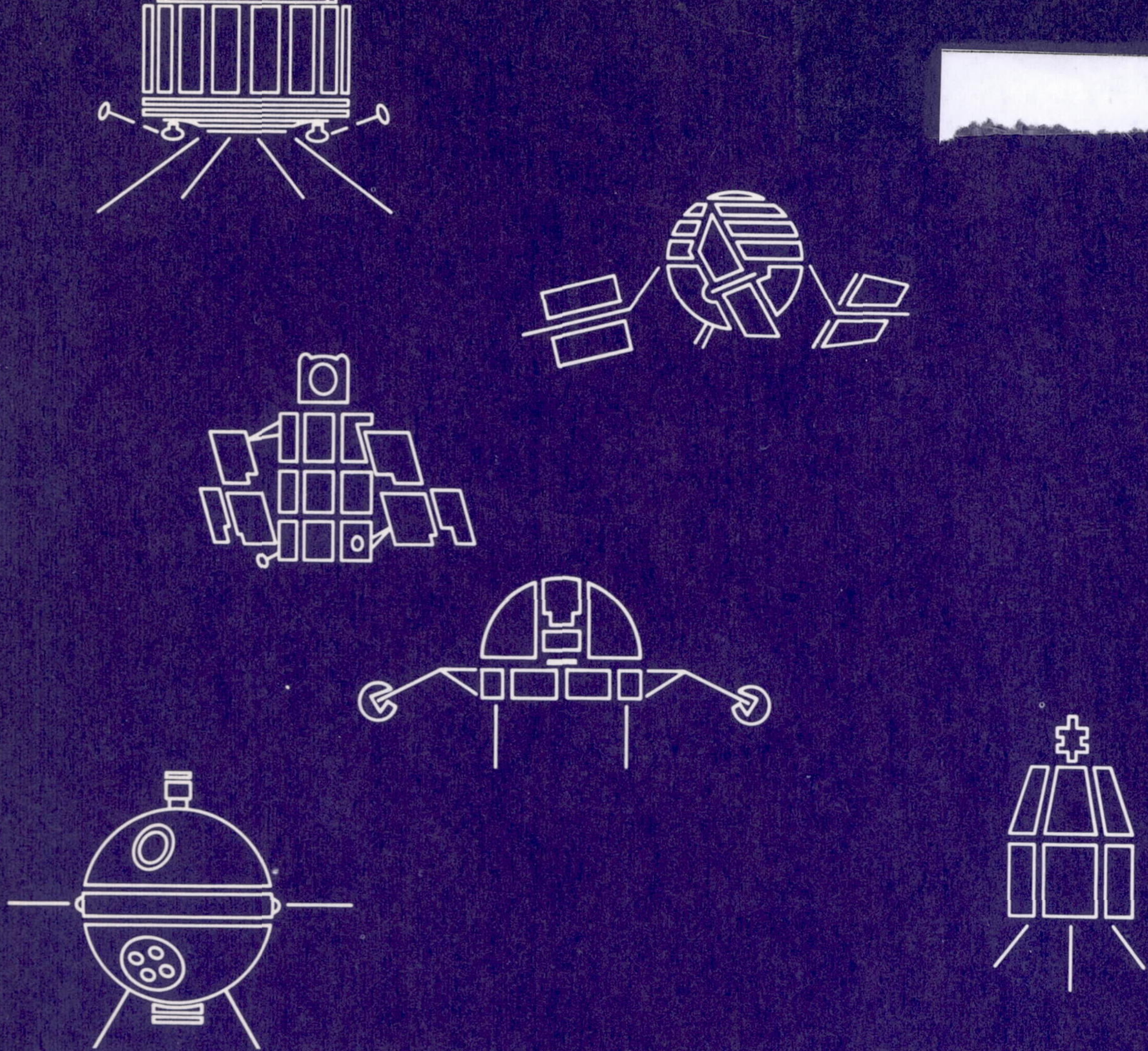
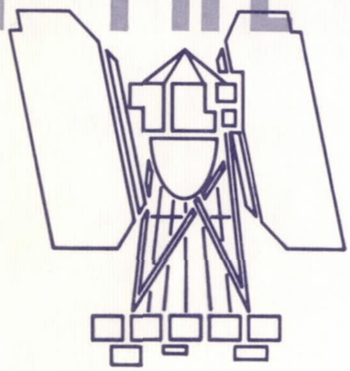
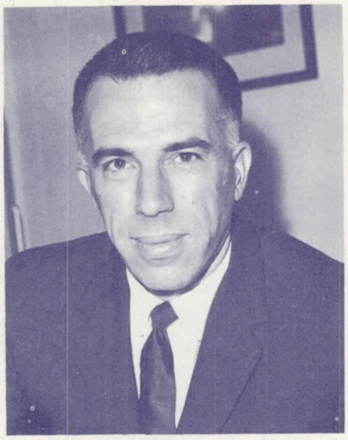


UNMANNED SPACECRAFT OF THE UNITED STATES



BY EDGAR M. CORTRIGHT, Deputy Associate Administrator for Space Science and Applications

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



EDGAR M. CORTRIGHT

Deputy Associate Administrator for Space Science and Applications

Edgar M. Cortright was appointed Deputy Associate Administrator for Space Science and Applications on November 1, 1963. In this position, he shares responsibility with Dr. Homer Newell, Associate Administrator for Space Science and Applications, in planning and directing NASA's programs for the unmanned scientific exploration and utilization of space. These programs include the lunar and planetary probes, the geophysical and astronomical satellites and probes, biosciences, applications satellites, and the development and use of light and medium launch vehicles through the Atlas-Centaur class.

Mr. Cortright joined the National Advisory Committee for Aeronautics, the predecessor of NASA, as an aeronautical research scientist at Lewis Flight Propulsion Laboratory (now Lewis Research Center) in 1948. From 1949 to 1954, he was head of the Small Supersonic Tunnels Section; from 1954 to 1958, he was Chief of the 8 x 6-foot Supersonic Wind Tunnel Branch. In January 1958, he was appointed Chief of the Plasma Physics Branch.

When NASA was organized, Mr. Cortright became Chief of Advanced Technology Programs and directed initial formulation of NASA's meteorological satellite program, including TIROS and Nimbus. Later, he became Assistant Director for Lunar and Planetary Programs in the former Office of Space Flight Programs. On November 1, 1961, Mr. Cortright was appointed Deputy Director of NASA's Office of Space Sciences.

A native of Hastings, Pennsylvania, Mr. Cortright served as an officer in the U.S. Navy from 1943 to 1946. He earned a Bachelor of Aeronautical Engineering degree in 1947 and a Master of Science in Aeronautical Engineering degree in 1948, both from Rensselaer Polytechnic Institute.

During his research career, before the establishment of NASA, Mr. Cortright specialized in high-speed aerodynamics, particularly problems related to air induction system design, jet nozzle design, and interactions of a jet with external air flow. He is the author of numerous technical reports and articles. He is an Associate Fellow of the Institute of the Aeronautical Sciences. He is a recipient of the Arthur S. Flemming Award for 1963.

Mr. Cortright is married to the former Beverly Hotaling. Mr. and Mrs. Cortright and their two children, Susan J. and David E., live at 6909 Granby Street, Bethesda, Maryland.

UNMANNED SPACECRAFT OF THE UNITED STATES

BY EDGAR M. CORTRIGHT, Deputy Associate Administrator for Space Science and Applications

In 1957 the first earth satellite ushered in the age of space flight. Since that historic event, space exploration has become a major national objective of both the United States and the Soviet Union. These two nations have attempted a total of well over 200 space flight missions. Other nations are also participating in various degrees in what will continue to grow as a cooperative world effort.

In the years since 1957, man has successfully flown in earth orbit. He has initiated programs to land on the moon and return. He has made dramatic applications of earth satellites in meteorology, communications, navigation, and geodesy.

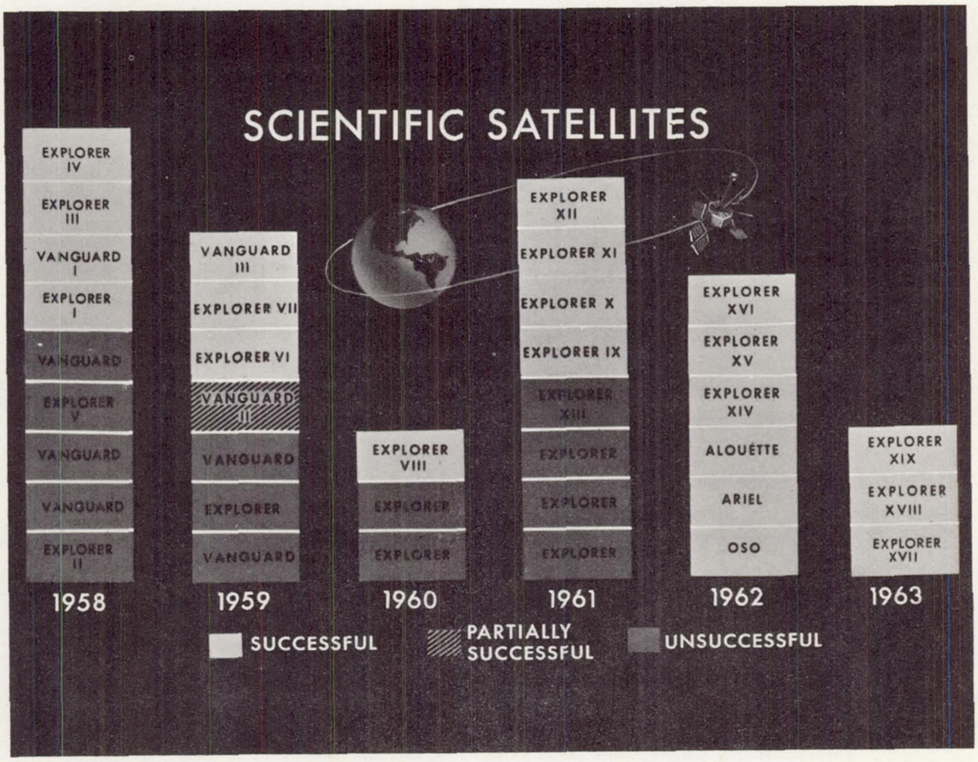
A host of scientific satellites continue to advance understanding of the earth's environment, the sun, and the stars. Automated spacecraft are being flown to the moon, deep into interplanetary space, and to the near planets, Mars and Venus.

One of the most exciting technological aspects of space exploration has been the development of automated spacecraft. Most of the scientific exploration of space and the useful applications of space flight thus far have been made possible by automated spacecraft. Development of these spacecraft and their many complex subsystems is setting the pace today for many branches of science and technology. Guidance, computer, attitude control, power, telecommunication, instrumentation, and structural subsystems are being subjected to new standards of light weight, high efficiency, extreme accuracy, and unsurpassed reliability and quality.

This publication reviews the automated spacecraft which have been developed and flown, or which are under active development in the United States by the National Aeronautics and Space Administration. From the facts and statistics contained herein, certain observations can be made and certain conclusions drawn.

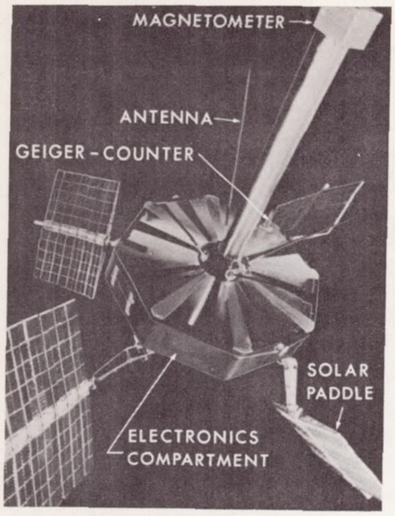
SCIENTIFIC SATELLITE HISTORY

Flight experience with scientific satellites through 1963 is summarized in the chart on this page. This experience illustrates the gradual maturing of the United States program to its record of 100% successful missions in 1962 and 1963. (This includes the Canadian-built satellite, Alouette, and the British-instrumented satellite, Ariel.) Prior to 1962, the more modest success rate was almost entirely attributable to the use of unproven launch vehicles which have since been discarded. With one exception, Vanguard II, all satellites performed quite well when successfully orbited, at least during their initial days of operation. Among the prime lessons learned from these early experiences were the following: (1) To accomplish effectively space exploration, one should develop a limited family of reliable launch vehicles and *use* them; (2) Long-lived satellites are required to observe and monitor space phenomena; (3) Reliability and long life are the two most important ingredients of economical space exploration; (4) Reliability is best achieved on the ground; by sound design, skilled workmanship, strict quality control, and a very thorough environmental test program. I will have more to say about these points later.



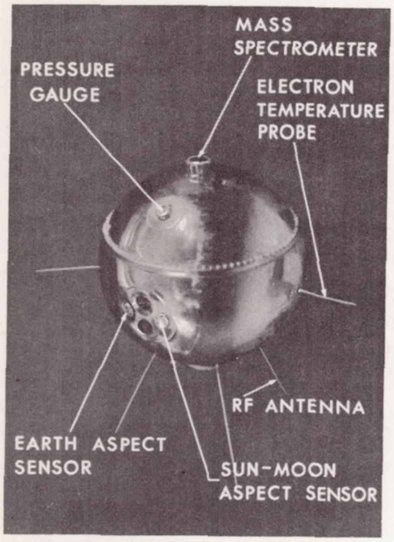
TYPICAL SCIENTIFIC SATELLITES

EXPLORER XII



GROSS WEIGHT—83 LBS • INSTRUMENT WEIGHT—18 LBS • EXPERIMENTS—6 • POWER—16 WATTS • STABILIZATION—SPIN • DESIGN LIFE—1 YEAR • LAUNCH VEHICLE—DELTA • ORBIT—APOGEE 41,717 NM PERIGEE 158 NM INCLINATION 33° • STATUS—LAUNCHED 15 AUGUST 1961.

EXPLORER XVII

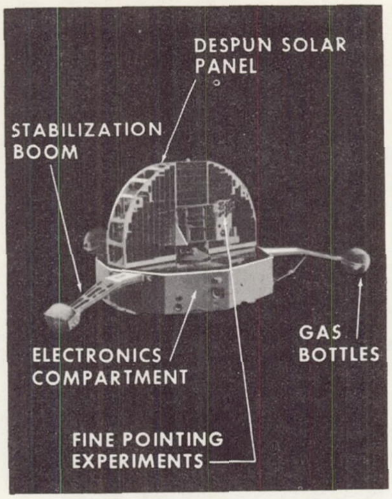


GROSS WEIGHT—410 LBS • INSTRUMENT WEIGHT—47 LBS • EXPERIMENTS—8 • POWER—110 WATTS • STABILIZATION—SPIN • DESIGN LIFE—3 TO 4 MONTHS • LAUNCH VEHICLE—DELTA • ORBIT—APOGEE 495 NM PERIGEE 138 NM INCLINATION 57.6° • STATUS—LAUNCHED 2 APRIL 1963.

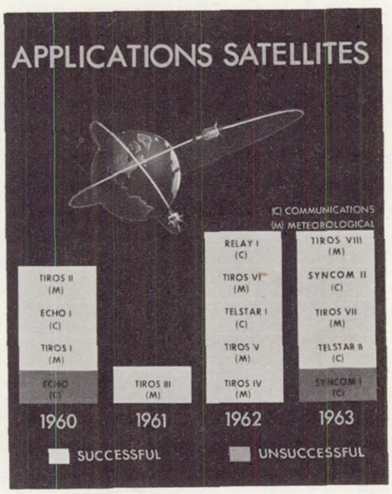
Explorers XII, XVII, and the Orbiting Solar Observatory, are representative of scientific satellites launched to date. Explorer XII is typical of a series of geophysical satellites designed to survey the earth's magnetosphere, the magnitude and direction of the earth's magnetic field, the charged particles trapped therein, and the flux of solar and galactic cosmic rays. Accordingly, the satellite is designed to operate in highly elliptical orbits. It features the simple spin stabilization and solar power system used on many of our satellites. Another area of geophysics being studied with satellites is the structure of the atmosphere. Explorer XVII was launched in 1963 and is unique in that it measures atmospheric temperature, pressure, and composition directly. In order to eliminate all possible sources of contamination from the spacecraft itself, including vaporizing solids, all equipment was hermetically sealed within a stainless steel shell.

Another satellite already flown is the Orbiting Solar Observatory (OSO). The OSO is unique in many respects. It was the first true observatory in orbit, and was designed to point selected experiments at the center of the sun with the direction measurable to within one minute of arc. These experiments are mounted on the solar panel which is despun by gas jets in the course pointing mode and finely pointed by electric servomotors to an accuracy of between 2 and 3 arc-minutes. This spacecraft must reacquire and stabilize on the sun once each orbit, which it has done thousands of times with great precision since its launching well over two years ago. Below this pointing section is a spinning electronics compartment

ORBITING SOLAR OBSERVATORY



GROSS WEIGHT—454 LBS • INSTRUMENT WEIGHT—173 LBS • EXPERIMENTS—13 • POWER—16 WATTS • STABILIZATION—SPIN • DESIGN LIFE—6 MONTHS • LAUNCH VEHICLE—DELTA • ORBIT—APOGEE 322 NM PERIGEE 299 NM INCLINATION 33° • STATUS—LAUNCHED 7 MARCH 1962.



whose plane of rotation includes the sun. This section, spinning at 30 rpm, carried experiments which thus saw the sun for 2 seconds per revolution. Another feature worth noting is the very high ratio of instrument weight to gross weight.

With regard to that important area called ionospheric physics, the Canadian Satellite Alouette, is particularly noteworthy. Alouette, which utilizes the topside sounding technique, has had an outstanding flight record. There were a minimum of malfunctions during developmental testing, and Alouette is functioning perfectly after almost two years in orbit and has recorded thousands of ionograms. It has not even been necessary to activate any of the redundant systems built into this satellite.

APPLICATION SATELLITE HISTORY

Experience with applications satellites has been even more encouraging as shown in the chart on this page. There have been only two mission failures since the program began in 1960. The initial attempt to launch the Echo communications satellite was the first and only failure of the Delta launch vehicle. Because of prior experience with stages of the Delta, however, it was possible to correct the deficiencies so that all nineteen subsequent Delta launches have been entirely successful. Because all of the applications satellite missions except TIROS I were based on the Delta, the spacecraft have had unparalleled opportunities to perform. All of the NASA satellites and the two Telstar satellites sponsored by private industry were successful except for the first Syncom, which malfunctioned after achieving a near 22,300 mile circular orbit.

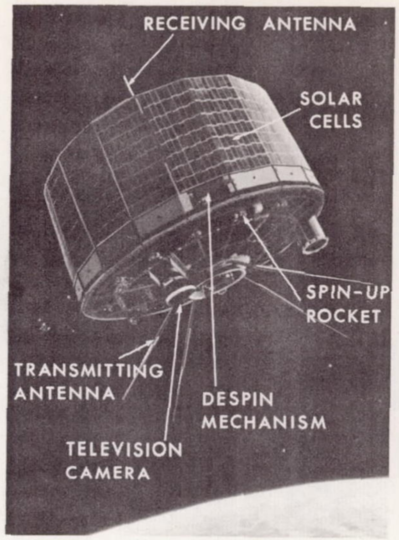
TYPICAL APPLICATIONS SATELLITES

TIROS VI, Relay, and Syncom are typical of the many applications satellites launched to date. TIROS VI is spin-stabilized, as were most first generation satellites, but has an added feature of a magnetic coil which can interact with the earth's magnetic field and precess the spin axis on command. Picture taking is limited to 32 stored pictures per orbit taken along the spin axis. It is planned that a later version of this spacecraft will be magnetically torqued so that the spin axis is parallel to the earth's surface. On this satellite, the two cameras will be pointed perpendicular to the spin axis so as to see the earth twice during each revolution throughout the entire orbit. In another experiment, TIROS may be flown to a 22,300-mile apogee to explore the effectiveness of weather photography from that altitude. Thus, this spacecraft has shown an excellent and somewhat unexpected growth capability.

The Relay satellite, like Telstar, is an experiment in wide bandwidth communications via signal relay beyond the horizon by an active transponder aboard a satellite. Relay differs from Telstar in its communication frequencies as well as its design details. Both spacecraft achieved most of their design objectives including high quality real-time television transmission between Europe and the North American continent. An operational system would include at least 20 to 30 such satellites.

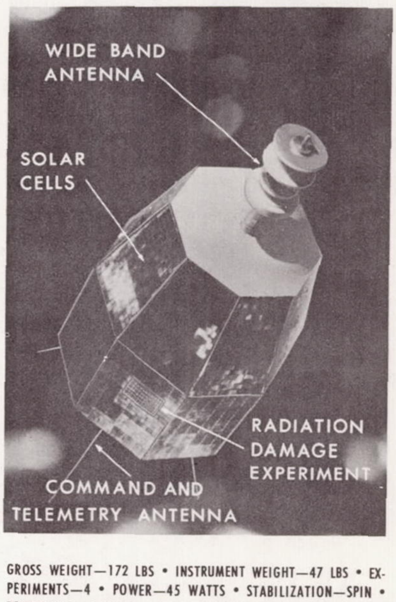
The Syncom communication satellite is designed for operation at 22,-300 miles altitude. At this altitude, it takes only three operating satellites to provide worldwide coverage at all but very high latitudes. Quasi-fixed

TIROS VI



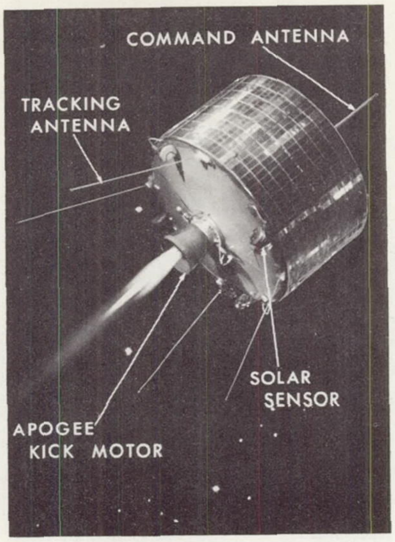
GROSS WEIGHT—281 LBS • INSTRUMENT WEIGHT—72 LBS • EXPERIMENTS—2 TV CAMERAS • POWER—20 WATTS • STABILIZATION—SPIN • DESIGN LIFE—4 MONTHS • LAUNCH VEHICLE—DELTA • ORBIT—APOGEE 390 NM PERIGEE 368 NM INCLINATION 58° • STATUS—TIROS VI LAUNCHED 18 SEPTEMBER 1962.

RELAY SPACECRAFT

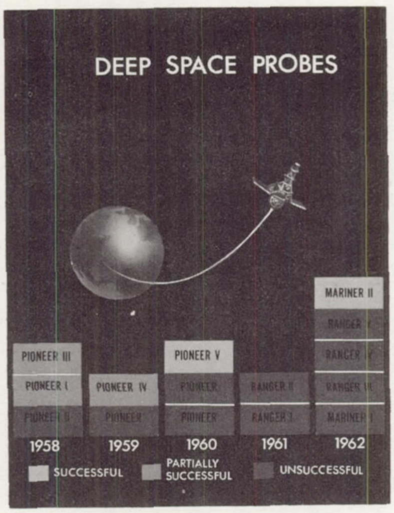


GROSS WEIGHT—172 LBS • INSTRUMENT WEIGHT—47 LBS • EXPERIMENTS—4 • POWER—45 WATTS • STABILIZATION—SPIN • DESIGN LIFE—1 YEAR • LAUNCH VEHICLE—DELTA • ORBIT—APOGEE 4012 NM PERIGEE 714 NM INCLINATION 47.5° • STATUS—RELAY I LAUNCHED 13 DEC 1962.

SYNCOM SPACECRAFT



GROSS WEIGHT—150 LBS • INSTRUMENT WEIGHT—40 LBS • POWER—25 WATTS • STABILIZATION—SPIN • DESIGN LIFE—ONE YEAR • LAUNCH VEHICLE—DELTA • ORBIT—APOGEE 19,987 NM PERIGEE 18,703 NM INCLINATION 33° • STATUS—LAUNCHED 13 FEB 1963.



but large ground antennae are required. The first Syncom achieved its orbit but failed to function thereafter. Syncom II, however, has been successfully orbited and maneuvered precisely onto a predetermined station. It is working well and on August 23, 1963 was used for the first telephone conversation between heads of state via satellite transmission. (The United States and Nigeria.)

DEEP SPACE PROBE HISTORY

In contrast with scientific and applications satellite missions, experience with deep space probes as depicted on the chart, has recorded few complete successes to date. Pioneer IV was the first United States space probe to reach escape velocity and orbit the sun, and was NASA's first successful deep space mission. Communication was maintained with the Pioneer spacecraft to 22.5 million miles. Since Pioneer V, the outstanding Mariner II flight to Venus has been NASA's only completely successful deep space mission. Whereas prior to 1962 all failures resulted from launch vehicle malfunctions, 1962 saw three Ranger spacecraft experience malfunctions on their flights to the moon.

There are some additional lessons here. The deep space missions are the most difficult of all automated spacecraft missions. They demand the utmost in performance from both launch vehicles and spacecraft. NASA's newest and least-developed launch vehicles must be used for these missions; and the spacecraft will continue to be complicated. It will be very difficult to equal the reliability of earth satellite missions with missions to the Moon, Mars, and Venus.

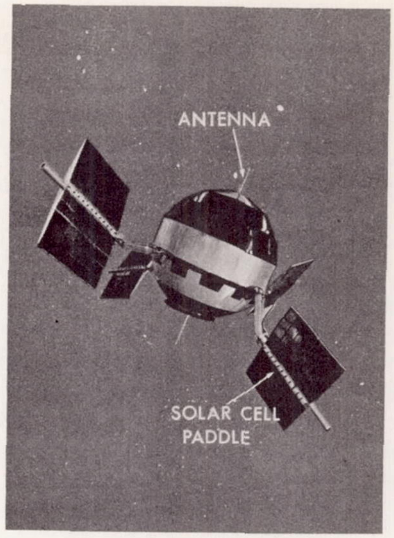
TYPICAL DEEP SPACE PROBES

Pioneer V, Ranger, and Mariner illustrate past spacecraft experience with interplanetary, lunar, and planetary flight, respectively.

Pioneer V was a spin-stabilized, solar-powered spacecraft bred from earth satellite technology. It was designed to make particle and field measurements in interplanetary space. The success of this relatively simple spacecraft in returning valuable data from up to 22.5 million miles convinced NASA that interplanetary monitors of this type should become a basic part of its program. NASA will begin a new Pioneer series in 1965 in support of the International Quiet Sun Year (IQSY).

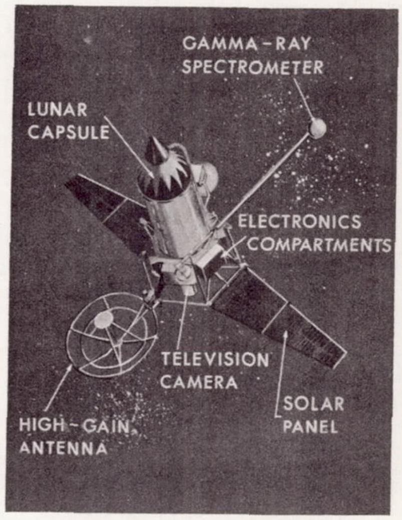
The Ranger is really a second or third generation spacecraft. It was designed to fly to the moon and land an instrumented capsule at a velocity of less than 250 feet per second within a fifty-mile circle. Because of the unique requirements of this mission, Ranger incorporated a number of technical innovations. Three-axis stabilization was achieved with an earth sensor, which pointed the directional antenna and locked the spacecraft in roll, and with a sun sensor which pointed the roll axis and solar panels at the sun and locked the spacecraft in pitch and yaw. The spacecraft could be programmed to any attitude for a midcourse velocity correction capable of reducing the dispersion at the moon from several thousand miles to about fifty miles. After the midcourse maneuver was complete, Ranger could reacquire its earth-sun lock until arrival at the moon. Upon arrival, the Ranger could be programmed to the proper attitude to align its capsule retrorocket axis with

PIONEER V SPACECRAFT



GROSS WEIGHT—95 LBS • INSTRUMENT WEIGHT—9.5 LBS • EXPERIMENTS—4 • POWER STEADY—15 WATTS PEAK—100 WATTS • STABILIZATION—SPIN • LAUNCHED—11 MARCH 1960 • LAUNCH VEHICLE—THOR-ABLE • TRAJECTORY—INTERPLANETARY: COMMUNICATED TO 22.5 MILLION MILES.

RANGER SPACECRAFT (3-5)

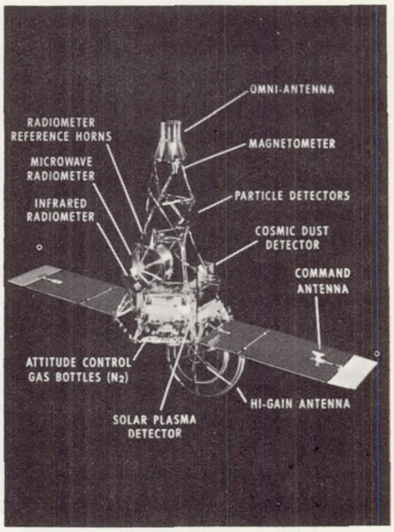


GROSS WEIGHT—756 LBS • PAYLOAD WEIGHT—147 LBS • EXPERIMENTS—4 • POWER—130 WATTS • PROPULSION—MID-*COURSE-MOTOR (LIQUID)* CAPSULE *RETRO-(SOLID)* • STABILIZATION—ACTIVE 3 AXIS • LIFE—66 HR. TRANSIT 30 DAY CAPSULE • LAUNCH VEHICLE—ATLAS-AGENA B • TRAJECTORY—LUNAR IMPACT VIA PARKING ORBIT • STATUS—3 SPACECRAFT LAUNCHED IN 1962.

the vertical descent velocity vector. The retrorocket would be triggered by a radar altimeter and would slow down the instrument capsule to a probable resultant impact velocity of less than 250 feet per second. The extremely sensitive seismometer capsule could withstand this impact by virtue of a ruggedized design and a protective layer of balsa wood. On the most successful of the three flights made with this spacecraft, it performed all automatic functions properly prior to arrival at the moon and executed the first midcourse correction made by a spacecraft. Two of the Rangers hit the moon but none returned lunar data. Plans call for additional Rangers of this type.

Mariner II was by far NASA's most successful deep space probe. Its attitude control and midcourse maneuver subsystems were functionally similar to those of the Ranger just described. On its 109-day, 180-million-mile flight to Venus, Mariner II performed beautifully despite minor problems including excessive temperatures, a solar-panel short, and a weak earth sensor signal. Less than 4 pounds of nitrogen were consumed for attitude control. Mariner's midcourse maneuver corrected the Venus miss distance from about 233,000 miles to 21,000 miles. Mariner was intended to miss Venus by 10,000 miles but was designed to scan Venus effectively at a distance of as much as 40,000 miles. All experiments worked very well and returned invaluable radiometric observations of the planet's atmosphere and surface. The telemetry signal strength at earth was less than 10^{-18} watts but was well within the design signal-to-noise ratio. The technology developed by Ranger and Mariner will continue to be used in NASA lunar and planetary spacecraft.

MARINER II



GROSS WEIGHT—449 LBS • INSTRUMENT WEIGHT—40 LBS • EXPERIMENTS—6 • POWER—150 WATTS • STABILIZATION—ACTIVE 3 AXIS • DESIGN LIFE—4 MONTHS • LAUNCH VEHICLE—ATLAS-AGENA • TRAJECTORY—INTERPLANETARY, VENUS FLY-BY AT 21,600 MILES • STATUS—MISSION SUCCESSFULLY COMPLETED ON 14 DECEMBER 1962.

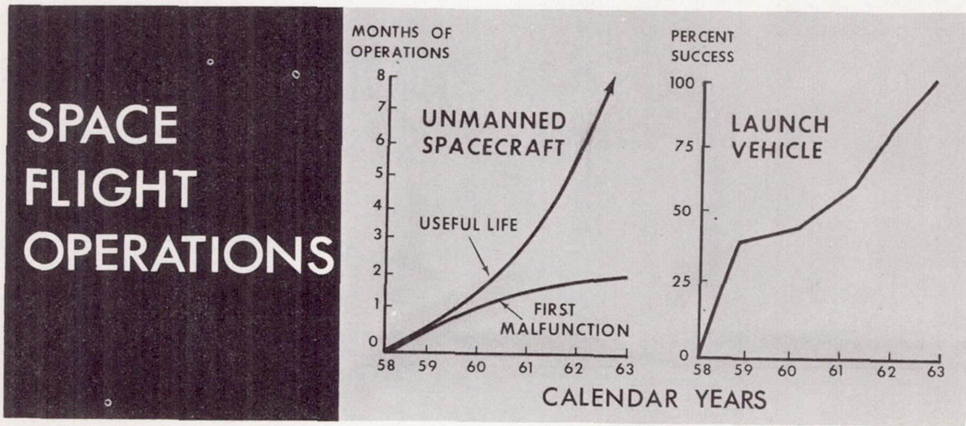
SPACECRAFT GROUND TEST EXPERIENCE
(AVERAGE OF 5 EXPLORER TYPE SATELLITES)

TEST	ELECTRICAL FAILURES		MECHANICAL FAILURES		TOTAL	
	NO.	%	NO.	%	NO.	%
CHECKOUT	2.4	13	1.2	26	3.6	16
VIBRATION	4.0	22	2.8	61	6.8	30
TEMPERATURE	.6	3	—	—	.6	3
VACUUM	1.0	6	—	—	1.0	4
THERMAL VACUUM	10.2	56	.6	13	10.8	47
TOTAL	18.2	100	4.6	100	22.8	100

As noted earlier, there is no good substitute for extensive ground testing in the development of spacecraft. The table presents the test history of an average Explorer spacecraft. In the five test phases, checkout, vibration, temperature, vacuum, and thermal vacuum, this average spacecraft experienced 18.2 electrical failures and 4.6 mechanical failures. Most electrical failures occurred during thermal vacuum and most mechanical failures during vibration.

The long-term effectiveness of such thorough testing standards is illustrated in the graph entitled Space Flight Operations. The average time to the first malfunction of any sort in flight of all of NASA's unmanned spacecraft had climbed to about 2 months in 1963. The average useful life has reached eight months and is still rising because some spacecraft launched in prior years are still functioning at a useful level.

During the same time period, our space launch vehicles had risen to a demonstrated reliability of 100%, paced by the Delta, which has now had 22 out of 23 successful launches.



SPACECRAFT COMPLEXITY

A real challenge is involved in maintaining these upward reliability and life trends in the face of increasing complexity. The chart below illustrates this fact by listing the approximate number of piece parts by subsystem for three advanced spacecraft: Mariner II, which has been described, and the Surveyor and Orbiting Geophysical Observatory which are yet to be described. These spacecraft contain about 54,000, 82,000, and 100,000 parts respectively. A sizeable percentage are critical for effective mission performance. Only time will tell whether we have moved too fast to this degree of sophistication.

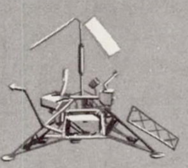
SPACECRAFT COMPLEXITY

MARINER II

TOTAL PARTS 54,000

SUB-SYSTEM	SCIENCE	TELE-COMMUNI-CATIONS	GUIDANCE & CONTROL	POWER	STRUCTURE	PROPULSION
PIECE PARTS	8,600	12,500	11,200	10,700	11,000	50

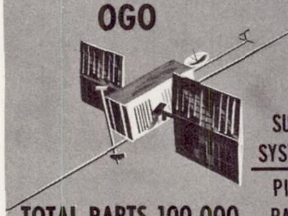
SURVEYOR



TOTAL PARTS 82,000

SUB-SYSTEM	SCIENCE	TELE-COMMUNI-CATIONS	GUIDANCE & CONTROL	POWER	STRUCTURE	PROPULSION
PIECE PARTS	19,300	23,600	18,600	5,900	12,500	2,700

OGO

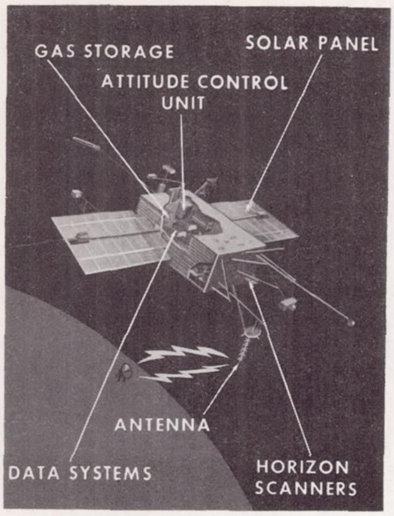


TOTAL PARTS 100,000

SUB-SYSTEM	SCIENCE	COMMUNI-CATION AND DATA HANDLING	STABILIZATION & CONTROL	THERMAL CONTROL	POWER	STRUCTURE
PIECE PARTS	24,000	34,200	2,600	2,000	33,500	4,000

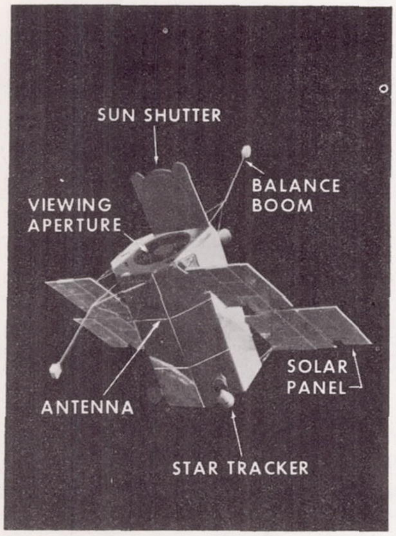
SPACECRAFT UNDER DEVELOPMENT

ORBITING GEOPHYSICAL OBSERVATORY



GROSS WEIGHT—1,000 LBS • INSTRUMENT WEIGHT—150 LBS • EXPERIMENTS—20 • POWER—500 WATTS • STABILIZATION—ACTIVE 3 AXIS • DESIGN LIFE—ONE YEAR • LAUNCH VEHICLES—ATLAS-AGENA THOR-AGENA • ORBITS—HIGHLY ELLIPTICAL INCLINED ORBIT—NEAR CIRCULAR POLAR ORBIT • STATUS—FIRST FLIGHT 1964.

ORBITING ASTRONOMICAL OBSERVATORY



GROSS WEIGHT—3,600 LBS • INSTRUMENT WEIGHT—1,000 LBS • EXPERIMENTS—11 • STABILIZATION—ACTIVE 3 AXIS • DESIGN LIFE—1 YEAR • LAUNCH VEHICLE—ATLAS-AGENA • ORBIT—CIRCULAR—434 NM INCLINATION 32° • STATUS—FIRST FLIGHT 1965.

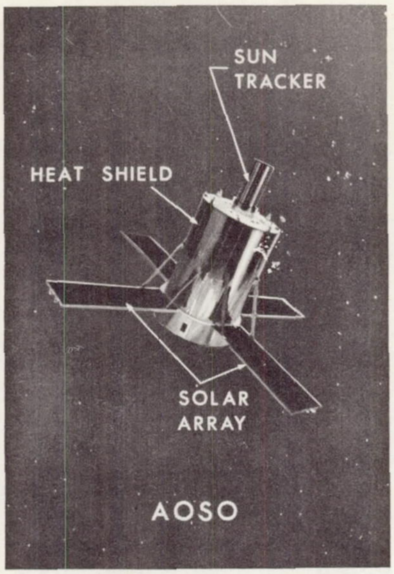
Among the most scientifically important spacecraft under development are the observatory class of satellites.

The Orbiting Geophysical Observatory (OGO), a 1000-pound satellite, is designed to carry from 20 to 50 experiments in either circular polar orbits at altitudes less than 1000 miles when launched with a Thor-Agena, or in highly eccentric inclined orbits with apogees of around 70,000 miles when launched with the Atlas-Agena. The spacecraft is designed to hold its attitude with the bottom looking directly toward the earth, its solar panels toward the sun, and selected experiments toward earth, space, sun, or in the direction of motion. A prime feature of the OGO is its data-handling system which can store up to 43.2 million bits of data at an input rate of 1000 to 4000 bits per second and a readout rate of 64,000 to 128,000 bits per second.

One of NASA's most ambitious and significant scientific satellites is the 3600-pound Orbiting Astronomical Observatory (OAO) to be placed in a 500-mile circular inclined orbit in 1965. Basically, the spacecraft is designed to sense and point the optical axis to any point in the celestial sphere, with the exception of a 90-degree cone about the sun line, to an accuracy of 1 minute of arc. Using the experimenter's prime optics and a suitable error sensor, the spacecraft control system is designed to achieve a fine pointing accuracy of 0.1 second of arc for extended periods of time. This has turned out to be a formidable task with which we are still having some problems. A combination of gas jets and inertia wheels are the prime movers.

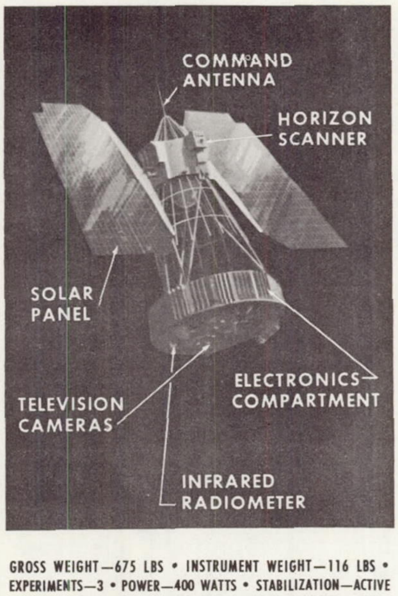
The scientific experiments aboard the OAO are among its most exciting features. Initial flights will stress the ultra-violet portion of the spectrum. The first flight will carry the sky survey experiment of the Smithsonian Astrophysical Observatory and the broad-band photometry experiment

ADVANCED ORBITING SOLAR OBSERVATORY



GROSS WEIGHT—900 LBS • INSTRUMENT WEIGHT—250 LBS • EXPERIMENTS—SEVERAL • POWER—400 WATTS • STABILIZATION—ACTIVE 3 AXIS • DESIGN LIFE—ONE YEAR • LAUNCH VEHICLE—AGENA • ORBIT—CIRCULAR 300 NM • STATUS—FIRST FLIGHT 1967.

NIMBUS



GROSS WEIGHT—675 LBS • INSTRUMENT WEIGHT—116 LBS • EXPERIMENTS—3 • POWER—400 WATTS • STABILIZATION—ACTIVE 3 AXIS • DESIGN LIFE—ONE YEAR • LAUNCH VEHICLE—THOR-AGENA • ORBIT—CIRCULAR 500 NM INCLINATION 80° RETROGRADE • STATUS—FIRST FLIGHT 1964.

of the University of Wisconsin which together total nine separate optical subsystems plus spectrometers. The second OAO will contain a NASA Goddard Space Flight Center system for the study of absolute spectrophotometry of several thousand stars and nebulae. This system features a 36″ primary mirror. The third unit will carry Princeton University equipment having a 32″ fuzed quartz primary mirror and intended for the study of interstellar matter.

A new observatory called the Advanced Orbiting Solar Observatory (AOSO) has recently been initiated. This observatory is designed for extensive and detailed observations of the sun not possible with the first generation OSO. The field of view will extend to about ten degrees centered on the solar disk; yet a 5 arc second pointing precision will permit some 400 observations in one pass across the sun's diameter. This will permit spectral analysis of individual sun spots and other detail structure. A particularly challenging technical problem is to locate and record in the brief time available major solar flares which occur relatively infrequently and emanate from a small portion of the solar disk.

The most advanced meteorological satellite is the Nimbus, designed to fly early in 1964. The 750-pound Nimbus will initially fly in a circular 80° retrograde orbit so that the orbital precession will maintain the earth illumination relatively constant (i.e., 12 o'clock noon orbit). The Nimbus is fully stabilized to look at the earth while its solar panels seek the sun. Multiple videcon TV cameras provide complete daylight observation of the earth once each 24 hours. Cloud pictures are stored for readout at two wide-band readout stations in Alaska and Canada, once each orbit. As a further service, the Nimbus will continuously transmit cloud pictures of a 1000-mile square immediately under the satellite to any user throughout the world willing to invest in some modest receiving and data-processing equipment.

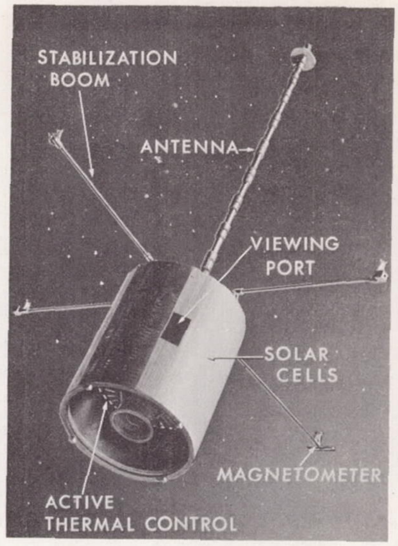
The follow-on Pioneer deep space probes are designed to monitor particles and fields at distances up to 50 to

90 million miles from earth. Two probes launched ahead of and trailing the earth, plus earth satellites, will make possible the monitoring of a large segment of the solar sector. This small probe will deliver a data rate of 16 bits per second up to 80 million nautical miles, with much higher rates early in the flight.

NASA's next planetary probe is a Mariner, designed to duplicate the Mariner II feat of a close planetary fly-by. In this case, however, the target is Mars. Although Mariner-Mars does not look much like Mariner II, it uses much of the same technology. Some interesting variations include the following: the use of a fixed high-gain antenna, made possible by the particular earth-sun-planet geometric relationships for this flight; a change from earth reference to Canopus reference for one axis; and the addition of solar pressure vanes at the tips of the solar panels to supplement and back up the gas stabilization system. The Mars mission is more difficult than the Venus mission because of increased lifetime, increased communication distance and power requirements, and a decreased solar constant. The Mariner-Mars payload will include a TV telescope for surface photography.

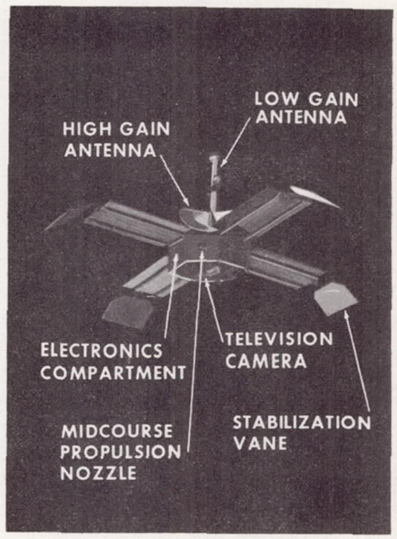
For the 1966 Mars mission, a version of this spacecraft will be fitted with a capsule to land and survive on the Martian surface. The Atlas-Centaur launch vehicle will be required. The capsule landing will not be attempted unless we can be assured that it is biologically sterile. The basic spacecraft, as on the 1964 flight, will not be sterile but will use a trajectory providing less than one chance in 10,000 of impact. From a technological point of view, we have found the use of heat, gas, liquids, and radiation to achieve complete spacecraft sterilization without degradation of reliability to be beyond the state of art at this time. Thus, lunar spacecraft, such as the Ranger and Surveyor to be described, will settle for surgically clean procedures which are now deemed sufficient for the moon.

PIONEER



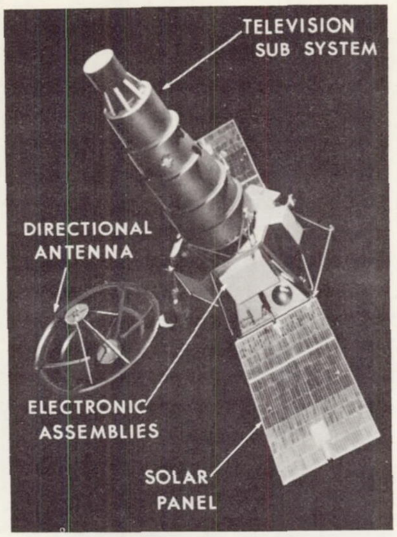
GROSS WEIGHT—115 LBS • INSTRUMENT WEIGHT—20 LBS • EXPERIMENTS—4 • POWER—50 WATTS • STABILIZATION—SPIN • DESIGN LIFE—6 MONTHS • LAUNCH VEHICLE—DELTA • TRAJECTORY—INTERPLANETARY • STATUS—FIRST FLIGHT 1965.

MARINER MARS



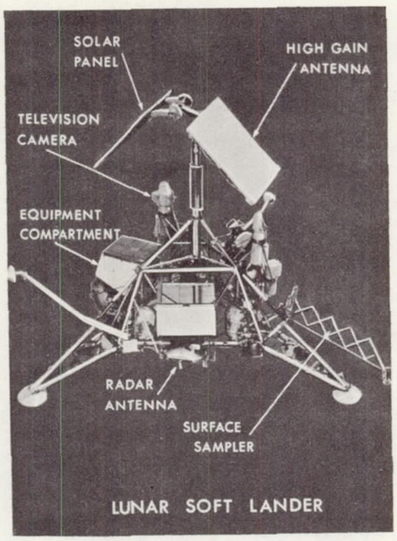
GROSS WEIGHT—570 LBS • INSTRUMENT WEIGHT—40 LBS • EXPERIMENTS—6 • POWER—120 WATTS • STABILIZATION—ACTIVE 3 AXIS • DESIGN LIFE—8 MONTHS • LAUNCH VEHICLE—ATLAS-AGENA • TRAJECTORY—INTERPLANETARY, MARS FLY-BY • STATUS—FIRST FLIGHT IN 1964.

RANGER (6-9)



GROSS WEIGHT—807 LBS • EXPERIMENT—TELEVISION (6 CAMERAS) • TELEVISION SUBSYSTEM WEIGHT—371 LBS • POWER—170 WATTS • PROPULSION—MIDCOURSE MOTOR (LIQUID) • STABILIZATION—ACTIVE 3 AXIS • LIFE—66 HR. TRANSIT • LAUNCH VEHICLE—ATLAS AGENA-B • TRAJECTORY—LUNAR IMPACT VIA PARKING ORBIT • STATUS—NEXT FLIGHT 1964.

SURVEYOR SPACECRAFT



GROSS WEIGHT—2,100 LBS • INSTRUMENT WEIGHT—100 LBS • EXPERIMENTS—8 • POWER—88 WATTS • STABILIZATION—ACTIVE 3 AXIS • PROPULSION RETROROCKET—SOLID • VERNIER ROCKETS—LIQUID • DESIGN LIFE—30-90 DAYS • LAUNCH VEHICLE—ATLAS-CENTAUR • TRAJECTORY—DIRECT ASCENT OR PARKING ORBIT • STATUS—FIRST FLIGHT 1964.

The next block of Ranger flights is scheduled as a series of four spacecraft, Rangers 6 through 9. These spacecraft are similar to those illustrated earlier, but with a high-resolution television subsystem substituted for the landing capsule and its retrorocket. This TV subsystem will take pictures of the lunar surface during descent. The last full frame before impact should resolve objects of about 1 meter in diameter within a square 60 meters on a side. These flights will provide spot sampling of the many conflicting theoretical models of the lunar surface. Our detailed surface reconnaissance must await the Surveyor and a lunar photographic orbiter on which work has recently been initiated.

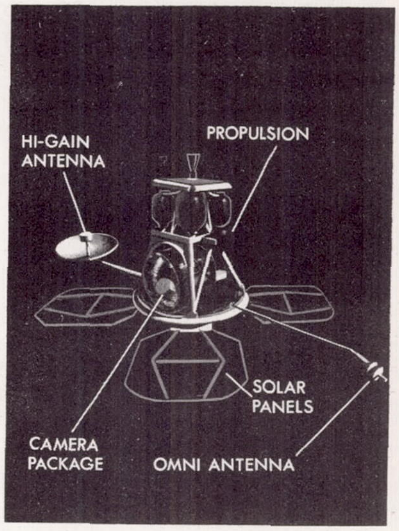
Surveyor, a 560-pound spacecraft, weighs 2150 pounds when coupled with its retrorocket. It will fly to the moon in a stabilized mode similar to the Ranger but with a Canopus rather than an earth sensor. Two midcourse maneuvers can be made with three small liquid rockets which are also used for landing. During descent, the main retrorocket is fired by a marking radar altimeter and attitude is maintained during this firing with the three small liquid rockets. After firing the main retrorocket is jettisoned and the Surveyor will land under its own control using a dual Doppler radar system. Once on the moon, the surface will be observed with television cameras, seismic activity will be monitored and local physical and chemical surface properties will be analyzed. Later Surveyors may carry a small roving vehicle. When these local sites are observed from orbit and interrelated with broad area photographic coverage, we should be in a good position not only to describe the moon scientifically with some accuracy, but to select a landing site for man.

The primary goal of the Lunar Orbiter is the photography of considerable areas of the lunar surface for the exploration and selection of landing sites for the Surveyor and Apollo missions. Additional investigations consist of measurements of the lunar gravity field and the environment of a near surface lunar orbit. On a typical mission, the spacecraft is launched from the AMR and injected into translunar trajectory by an Atlas/Agena booster. After separation from the Agena, the attitude control subsystem orients the spacecraft with the solar panels facing the sun and then rolls the spacecraft until the star sensor locks on Canopus. This attitude is maintained at all times except for midcourse correction, lunar orbit injection or transfer, or orientation for photography.

At approximately 72 hours after launch, the retro into lunar orbit is made at a nominal lunar altitude of 574 miles. After several orbits the elements of the spacecraft orbit are known from tracking by the Deep Space Instrumentation Facility with sufficient precision to command a retro maneuver into an elliptical orbit, which has a perilune altitude of 29 miles over the area of interest. Photographs are taken from this final orbit as the spacecraft passes over the specific target on one or more orbits, while telemetry records the conditions under which photos are taken. At this altitude, the photographic system is designed to provide coverage of 24,800 sq. miles at 26¼ feet resolution and 4,960 sq. miles at 3⅓ feet resolution.

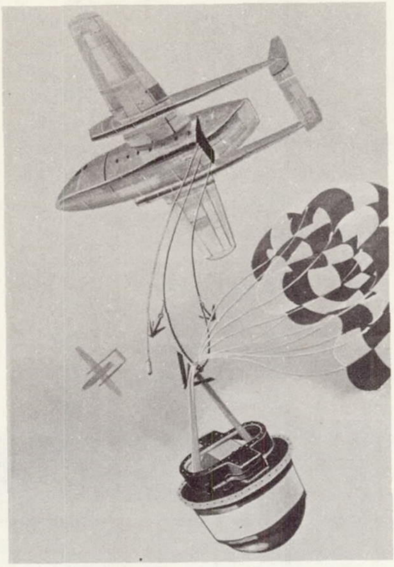
The Biosatellite program is designed to determine the biological effects on plants and animals of weight-

LUNAR ORBITER



GROSS WEIGHT—819 LBS • INSTRUMENT WEIGHT—116 LBS • INVESTIGATIONS—TELEMETERED FILM PHOTOGRAPHY-SELENODESY ENVIRONMENTAL MEASUREMENTS • POWER—245 WATTS (MAX) • STABILIZATION—3 AXIS • DESIGN LIFE—6 MONTHS TO 1 YR. 1 MONTH PHOTOG. • LAUNCH VEHICLE—ATLAS-AGENA • TRAJECTORY—ECCENTRIC LUNAR ORBIT • STATUS—DESIGN PHASE.

BIOSATELLITE



GROSS WEIGHT IN ORBIT—1175 LBS • RECOVERED CAPSULE—250 LBS • INVESTIGATIONS—WEIGHTLESSNESS, RADIATION, AND BIO-RHYTHMS • POWER—FUEL CELLS • TIME IN ORBIT—3 TO 30 DAYS • RECOVERY—AIR SNATCH OR WATER • LAUNCH VEHICLE—DELTA • ORBIT—CIRCULAR 230 MI. INCLINATION 28.5° • PLAN—SIX FLIGHTS, FIRST LAUNCH LATE 1965.

lessness, radiation, and the absence of a diurnal cycle. A series of six biosatellites are planned with the first flight scheduled for late 1965. The satellites will be launched from the AMR into a 230 mile circular orbit inclined at 28.5° to the equator. Biosatellites will remain in orbit for periods of 3 to 30 days depending upon the investigations being conducted.

The Biosatellite spacecraft consists of the re-entry vehicle, which contains the experiments along with the heat shield and recovery system, and an adapter, which houses all of the life support supplies and equipment required during orbital flight. The recovery capsule itself is sealed and temperature and humidity controlled. Upon completion of time in orbit a ground command will orient the spacecraft for separation of the re-entry vehicle and firing of the retrorocket. Upon re-entry, the capsule will be recovered in the air or from the sea.

SUMMARY

The automated spacecraft constitute a unique addition to the rapidly evolving engineering and scientific scene. From a technological point of view, they offer unique opportunities for imagination, creativity, design excellence, craftmanship, and skilled flight operations. From a scientific point of view, they offer a unique opportunity to extend our electronic sensors to distant worlds. In a broader sense, they offer a unique opportunity to weld scientists and engineers into a cooperative effort which can lead us—who knows where?

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DEFINITIONS

EARTH SENSOR—*a photoelectric device that detects the earth and provides a reference for spacecraft attitude control.*

NODES—*The points at which an earth satellite's orbit crosses the plane of the earth's equator.*

ORBITAL PLANE—*an orbit plane is the plane defined by the curved path of a satellite and passes through the center of the earth or other celestial object about which the satellite orbits.*

PRECESSION—*change in direction of the axis of rotation of a spinning body or of the plane of the orbit of an orbiting body when acted upon by an outside force.*

REDUNDANT SYSTEMS—*duplicate systems intended to prevent failure of the entire vehicle or spacecraft if a single system fails.*

RETROGRADE ORBIT—*An orbit, resulting from a launching to the west of a meridian, which precesses in the direction of the earth's rotation.*

SPECTROPHOTOMETRY—*measuring the intensities of radiation as a function of the frequency or wavelength of the radiation.*

SPIN STABILIZE—*maintaining a satellite's orientation by means of gyroscopic forces that result from its spinning.*

TOPSIDE SOUNDING—*a technique for measuring electron density in the ionosphere by transmitting radio signals downward from a point above the earth. Contrasted with bottomside sounding carried out by means of radio transmitters on the ground.*

TORQUE—*a turning or twisting force; that which tends to produce rotation of a body.*

TRANSPONDER—*a radio communications device consisting of receiving, amplifying, transmitting, and associated equipment that automatically responds and transmits when triggered by another signal, not necessarily on the same frequency as received.*

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