FUTURE SCIENTIFIC SPACECRAFT

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Satellites and space probes have proven to be extremely useful tools for the scientific exploration of space. Spacecraft carrying scientific instrumentation have returned large volumes of information on the earth's environment during the first six years of the Space Age, initiated October 4, 1957, with the successful launch of Sputnik 1. Although currently overshadowed by the Apollo manned lunar landing program, both in budget and publicity, a broad variety of future scientific spacecraft is planned by the National Aeronautics and Space Administration, and an increasing number of foreign governments are organizing space-research programs. This article will review the various scientific satellites and space probes to be launched in the next few years and will discuss their scientific objectives.

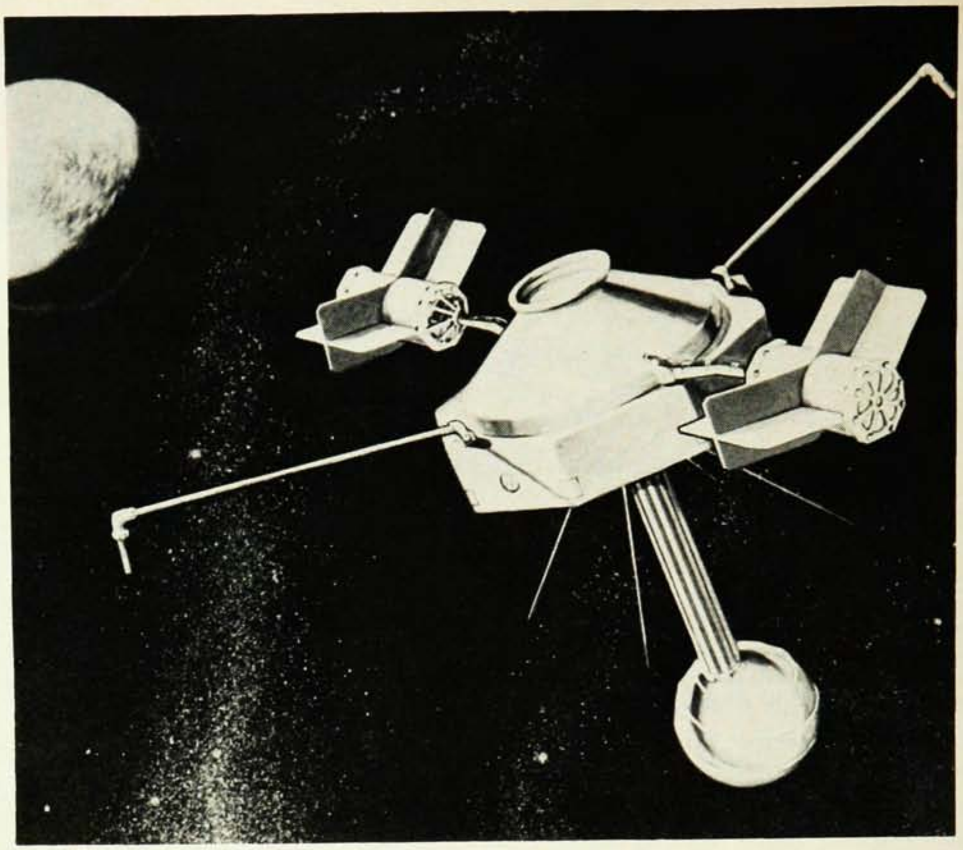
Explorer Program

The United States satellite space-research program was initiated with the successful orbit of Explorer 1 on January 31, 1958. Seventeen Explorer satellites have been orbited to date, primarily with particle and field experiments. The program will be diversified in the coming years to include a wide variety of investigations.

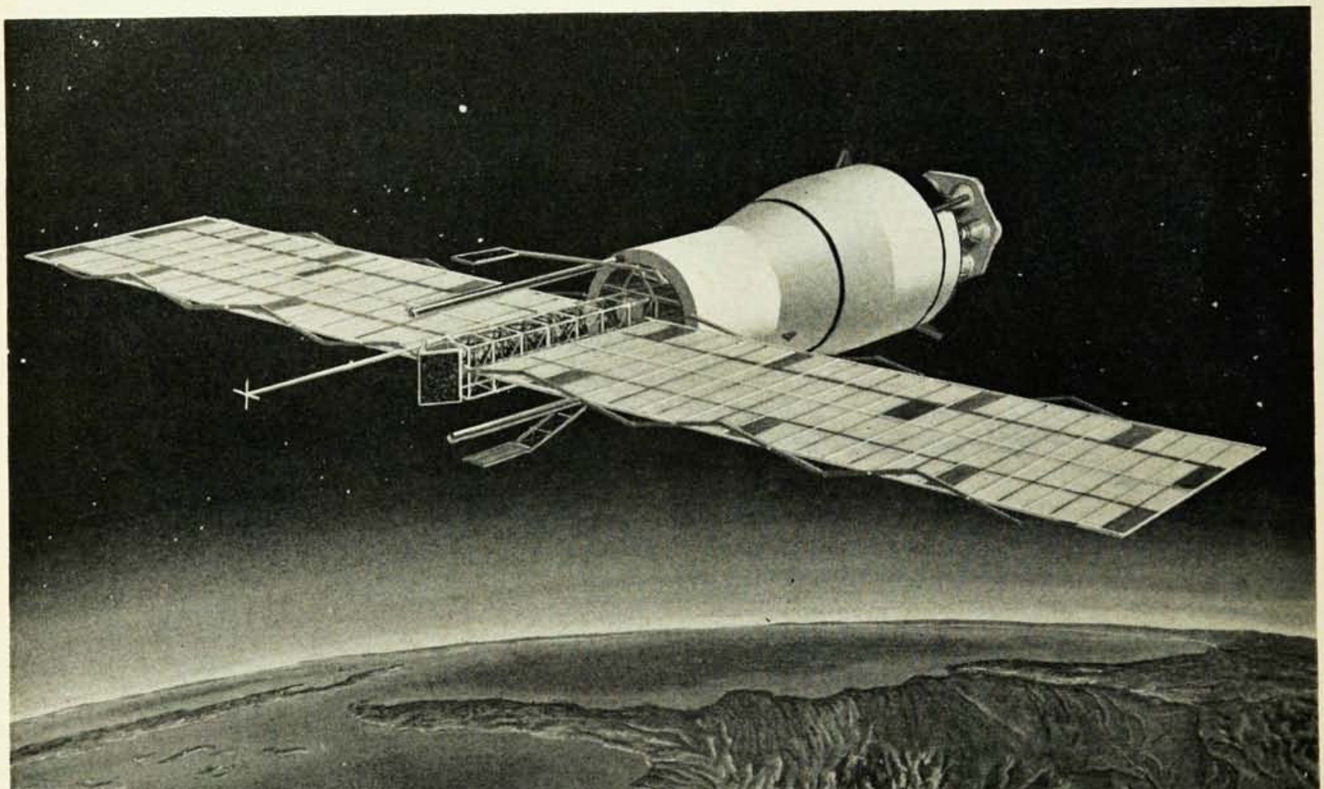
A polar ionosphere beacon satellite will be placed in circular polar orbit this year to measure the electron density of the ionosphere. More than forty scientists from the United States and abroad will participate in the experiments. The 120-pound spacecraft will be tracked by a pulsed ruby laser system at Wallops Island, Virginia, the first such laser application in the space program. Additional investigation of the ionosphere will be conducted with a fixed-frequency "topside sounder" satellite to be launched this year. The spacecraft will weigh 105 pounds and will complement the work of Canada's Alouette orbited in 1962. Other Explorers to be launched this year include a corpuscular radiation research satellite and another atmospheric structures satellite, similar to Explorer 17, to continue measurements of the density, composition, pressure, and temperature of the upper atmosphere.

A series of "monitor" spacecraft has also been initiated under the Explorer program to provide long-term observation of various phenomena. The first of this class of lightweight (125 pounds) but highly reliable spacecraft, an interplanetary monitoring probe, was successfully launched as Explorer 18 in November, 1963. The satellite was placed in a highly elliptical orbit with an apogee of 123 000 miles to study the interplanetary magnetic field, the solar wind, and cosmic rays. Additional spacecraft of this type will be periodically launched to provide continuous monitoring. In addition, long-life atmosphere and ionosphere monitors are being prepared for 1965 launches.

Development of a recoverable satellite to carry biological payloads for periods of up to thirty days is also under way, with initial launch set for late 1965. The basic 1000-pound "biosatellite" will be modified to carry three types of experiments: primate, with monkey passengers; radiation; biorhythm and general biology. The spacecraft will be seven feet long and about 44 inches in diameter. Its life-support system will include a life cell, environmental control system, biomedical instrumentation, telemetry equipment, and metabolic



Interplanetary monitoring probe satellites are to be launched periodically under the Explorer program in order to provide continuous, long-term observation of cosmic radiation, the interplanetary magnetic field, the solar wind, and other phenomena.



Meteoroid detection satellites will be carried on Saturn I test flights and injected into orbit. They will be used to determine the micrometeoroid hazard to manned spacecraft.

support, including a two-gas sea-level atmosphere. The satellite will be placed in a 200-mile circular orbit and will be reoriented prior to ejecting its re-entry capsule, to be recovered from the Pacific Ocean near the Hawaiian Islands.

Large, wing-like meteoroid detection satellites will be launched as secondary missions on board the eighth and ninth Saturn I launch vehicle test flights. Upon injection into orbit the satellite's two flat wings will be deployed by a system of scissor-like links driven by an electric motor. Four solar panels and a crossed dipole antenna will also be extended from the spacecraft. The two wings, each 15 x 50 feet, will be covered with aluminum-mylar capacitor sheets. A micrometeoroid penetration will discharge the capacitor and the resulting pulse will be stored in a memory circuit, then transmitted upon ground command. The meteoroid detection satellite's orbit will range from 300 to 800 miles; initial launch is scheduled for late 1964. Total weight of the satellite will be about 3400 pounds.

Orbiting Observatories

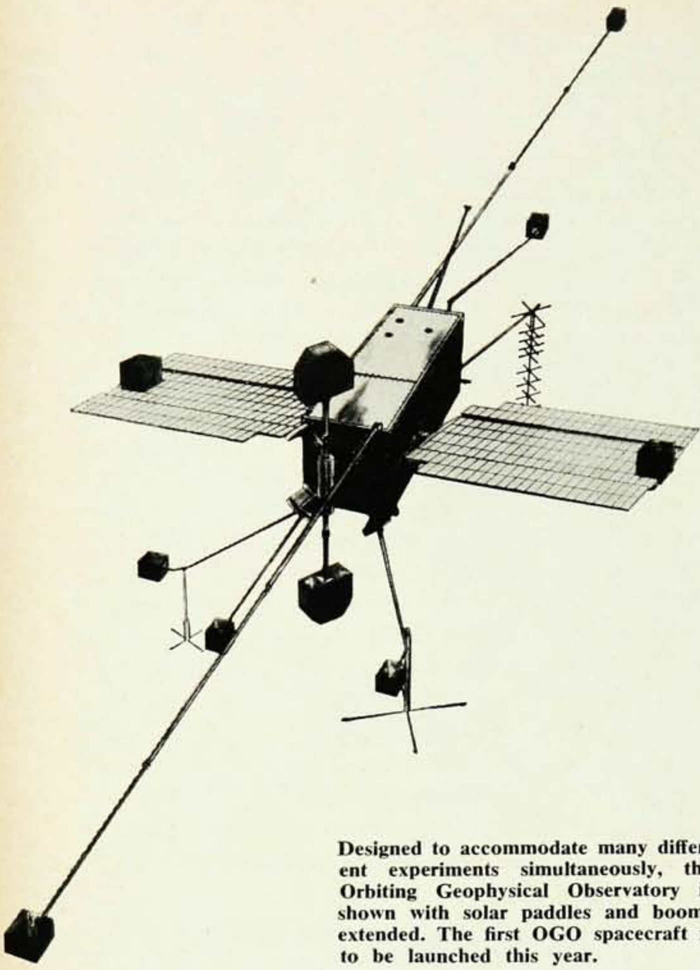
The Explorer program has contributed the majority of scientific spacecraft successfully orbited by the United States to date. The early Explorers have typically weighed under 200 pounds and have been designed to carry specific payloads of a limited number of experiments. NASA is now changing this pattern with its observatory class of earth satellites. Three observatory programs have been organized—solar, geophysical, and astronomical. Each will provide a heavy (400 to 4000 pounds), standardized satellite to carry a variety of experiments at six-month or yearly intervals. Each is designed for high reliability and will feature advanced attitude control systems and data storage and transmitting equipment. These programs greatly increase our capability to orbit experiments with a minimum of delay and at minimum expense.

The first observatory program, the Orbiting Solar Observatory (OSO), was successfully initiated in March, 1962, with the launch of OSO 1. This spacecraft, designed to point instruments at the sun from above the earth's atmosphere, weighed 458 pounds and returned a large quantity of data from thirteen experiments. The solar observatories carry a minimum of 175 pounds of instrumentation for measuring solar electromagnetic radiation in the ultraviolet, x-ray, and gamma-ray regions and are designed to be placed in approximately 300-mile orbits.

Up to seven additional OSOs will be launched in the next five years. The satellite is made up of two main components: a spin-stabilized base section and a fan-shaped section containing the principal solar experiments and a solar-cell array. The latter section stabilizes on the sun each orbit with a control system employing gas jets and electric servomotors. The pointing accuracy of OSO 1 was within ± 2.5 arc minutes in elevation and ± 1.0 arc minute in azimuth with respect to the center of the solar disk. The base section is composed of nine wedge-shaped compartments, six of which are available for experiments not required to point continuously at the sun. Three fiberglas balls extend on arms from the section and carry pressurized nitrogen gas for the spin-control system. The section, whose plane of rotation includes the sun, is designed to spin at thirty rpm.

Design of an Advanced Orbiting Solar Observatory (AOSO) was recently initiated. This version will first be launched in late 1967 and will be intended to complete solar observations over the full eleven-year cycle of sunspot activity. The AOSO will provide increased pointing accuracy over its predecessor, down to five arc seconds, to permit observations of a single sunspot on the sun's surface, plus improved control flexibility and data-handling capacity. The advanced model will weigh about 1000 pounds, including 250 pounds for experiments, and will be placed in 300-mile retrograde polar orbits.

The Orbiting Geophysical Observatory (OGO) will be the second standardized scientific earth satellite with sophisticated power supply, thermal control, attitude control, data handling, and communications systems. The OGO's modular compartments and booms will accommodate up to fifty geophysical experiments. It is thus possible to carry a relatively large number of related experiments, and newly conceived experiments can be flown earlier than was previously possible. Areas of investigation will include energetic particles, radio propagation and astronomy, interplanetary dust, magnetic fields, and atmospheric measurements. The first in the series, OGO A, will be launched in mid-1964. Some twenty experiments, including Faraday plasma probes, a cosmic-ray telescope, triaxial search coil and rubidium-vapor magnetometers, geiger counters, and ion traps from various government agencies and universities, will be on board. The observatory will be injected into a highly eccentric earth orbit with a perigee of 150 nautical miles and an apogee of 60 000 nautical miles. The second spacecraft scheduled, OGO B, will be placed in polar orbit late in 1964

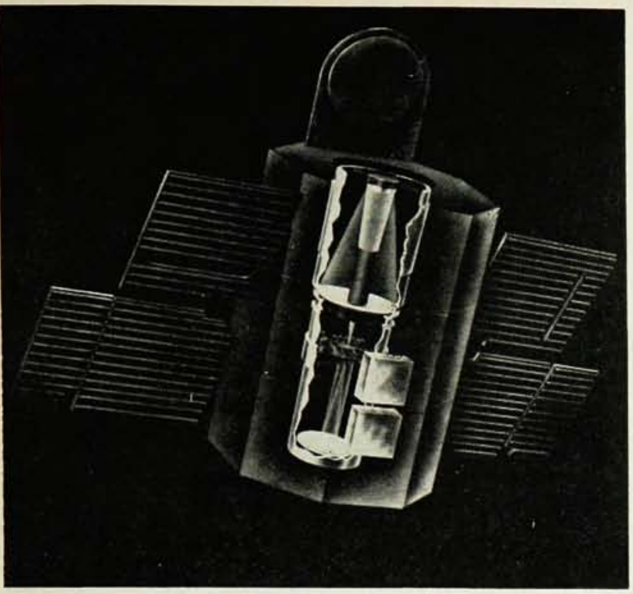


Designed to accommodate many different experiments simultaneously, the Orbiting Geophysical Observatory is shown with solar paddles and booms extended. The first OGO spacecraft is to be launched this year.

carrying twenty additional experiment packages. The OGO B satellite will have a perigee of 140 miles and an apogee of 500 miles. The first OGOs will weigh 1070 pounds, including 190 pounds for experiments; later models may weigh up to 1500 pounds and carry a 300-pound pickaback satellite to be injected into separate orbit.

With booms and solar paddles extended, OGO will have a total length of 54 feet and will be 20 feet wide. The satellite's main body will be 68 inches long and 33 inches square. Two large solar paddles will be attached to the main body, with instrument packages for solar observation mounted on each paddle, and two 22-foot booms and four 6-foot booms will extend from the spacecraft to house magnetometers and other experiments that might be affected by disturbances generated in the main body. Antennas and an attitude-control jet will also be boom mounted. Spacecraft systems and additional experiments will be located in the main body and mounted on doors on the top and bottom of the satellite. Thermally controlled louvers on the sides and one end will provide internal temperature control. Over 32 000 solar cells and two nickel-cadmium batteries will furnish the average observatory power requirements of 300 watts; experiments will use 50 watts of the total power supply. OGO's attitude-control system will employ horizon scanners and sun sensors to activate argon gas jets and reaction wheels; the satellite will be stabilized with the same side always facing the earth. Two orbital-plane experiment packages, located at one end of the satellite, will face forward in the orbital plane. Gyro control and a wabble gear drive will maintain these containers in the required direction. In addition, the solar paddles and associated experiment packages will be aligned toward the sun by a wabble gear drive. The spacecraft will yaw 180 degrees each half-orbit, if required, to prevent excessive solar array cable wrapup. OGO's data handling and communication system will include a redundant wideband telemetry system with two tape recorders and redundant transmitters, a second special purpose wideband system for real-time transmission, two command receivers, three tracking transmitters, and a master clock.

The Orbiting Astronomical Observatory (OAO) will make possible spectroscopic observations of the ultraviolet, infrared, and x-ray regions from a precisely stabilized platform above the obscuring effects of the earth's atmosphere. The first OAO is scheduled to be launched in 1965, with succeeding flights at six-month intervals. The OAO 1 will be placed in a 500-mile circular orbit and will carry two experiments, one mounted in each end of the spacecraft. The Smithsonian Astrophysical Observatory's experiment, Project Celescope, will be designed to produce a catalog of over 50 000 stars. In six months, three 12-inch Schwarzschild telescopes will survey the entire sky in four spectral bands, 1200-1600Å, 1300-1600Å, 1600-2900Å, and 2300-2900Å. A fourth telescope, serving as a slitless spectroscope, will provide additional information on the spectra of small nebulae and the brighter stars. A second experiment will measure the distribution of ultraviolet light in some two hundred selected stars and emission nebulae in the 800-3000Å region. One 16-inch and four 8-inch telescopes with filter photometers, plus two diffraction grating spectrometers, will be used in this experiment. Operation of the second experiment will be modified to take advantage of information gained from the Smithsonian survey. The second OAO will carry an experiment designed to obtain detailed data in the 1000-4000Å range on 14 000 stars a year using a 38-inch telescope and a spectrometer. An experiment to provide obser-



Astronomical observations of unprecedented clarity, carried out above the earth's atmosphere, are expected to be made possible by the Orbiting Astronomical Observatory (which is seen here in cutaway view, illustrating an arrangement of optical components). The first OAO spacecraft is scheduled to be launched sometime next year.

vations of interstellar gas in the 800-3000Å band will be carried on board OAO 3.

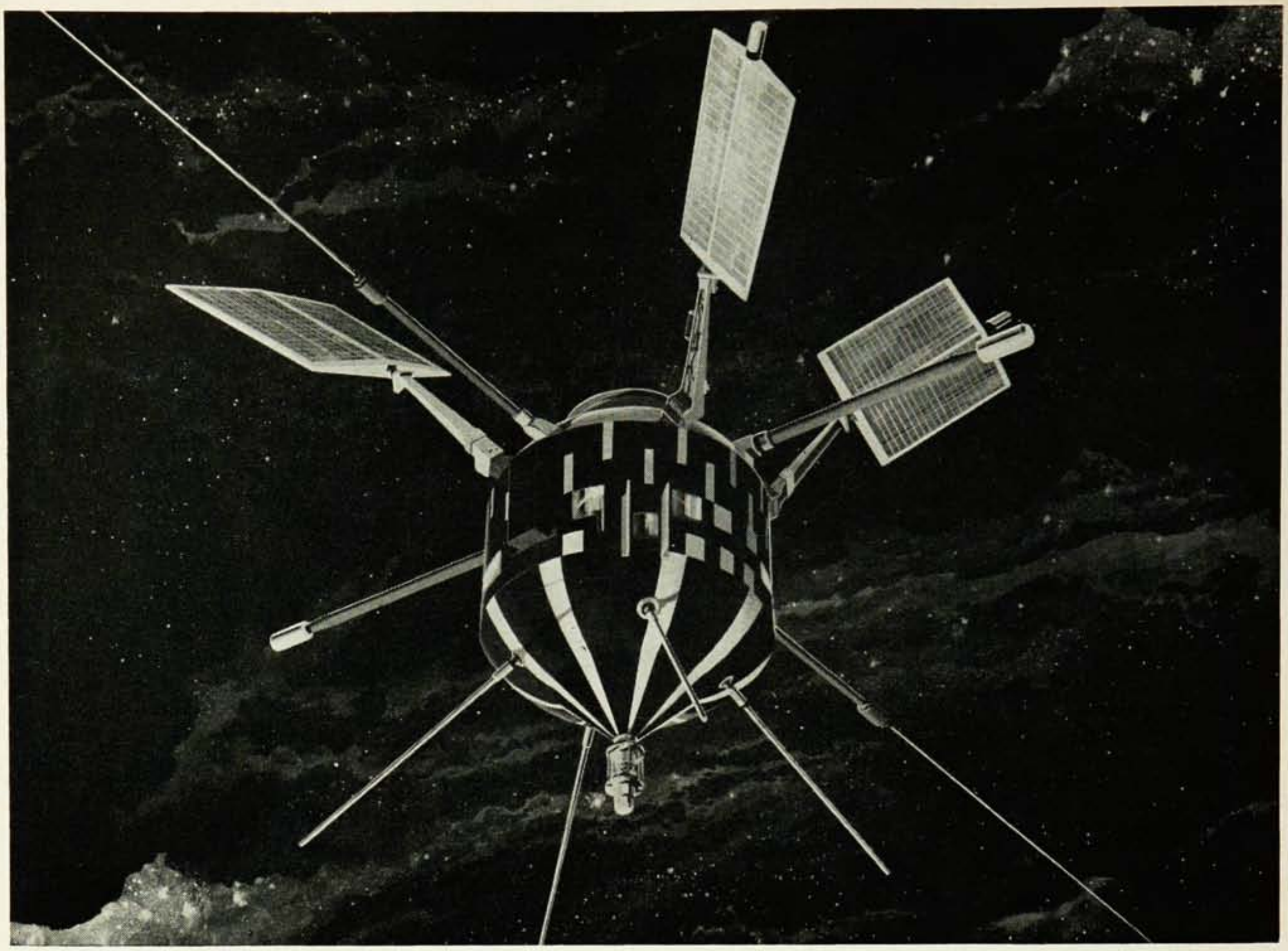
The octagonal spacecraft will be almost ten feet high and seven feet wide, with four large solar panels mounted on its sides. The observatory will weigh 3600 pounds, including experiments totaling 1000 pounds housed in a 48-inch central core running the length of the satellite. OAO's standardized subsystems will include a stabilization and control system employing a combination of star trackers, solar sensors, rate gyros, and a stellar television camera to provide orientation data. Coarse and fine reaction wheels, nitrogen gas jets, and magnetic torquing coils will stabilize the spacecraft, using experiment optics as an error source, to within an ultimate accuracy of 1/10 second of arc. The satellite will be in contact with a ground station for a maximum of only ten minutes per orbit; OAO therefore will carry a data-processing and memory system capable of storing over 200 000 bits of information. The satellite will utilize redundant tracking, telemetry, and command equipment. Eighty thousand solar cells mounted on both sides of the fixed solar panels in sawtooth array, plus nickel-cadmium batteries, will provide an average power supply of 300 watts. Constructed primarily of aluminum, the OAO will employ a passive thermal control system. The spacecraft will carry sunshades to protect the experiment packages at one or both ends, depending on the number of experiments on board.

Foreign Space Programs

Russian scientific satellite research has been concentrated in the Cosmos program in the last two years. An average of one satellite per month has been orbited since the first Cosmos launch in March, 1962. The first scientific results of the Cosmos series were contained in a USSR report to the COSPAR meeting held in Warsaw last June. The report listed the following Cosmos research areas: charged-particle density in the ionosphere, energy composition of the Van Allen belt, cosmic-ray composition and variations, geomagnetic field, ultrashort-wave electromagnetic radiation from the sun and other heavenly bodies, upper atmosphere, micrometeoroids, and cloud-cover formation and distribution. Weights and details of the satellites have not been released. In late January 1964, a new Soviet scientific program was initiated with the successful launch of dual Elektron satellites to simultaneously monitor the inner and outer zones of the Van Allen radiation belt.

NASA has cooperative agreements to launch and track satellites for several countries. Two scientific spacecraft, Great Britain's Ariel (UK 1) and Canada's Alouette, have already been orbited under this program, and both have provided extensive data on the ionosphere. The second British satellite, UK 2, is scheduled to be launched in the near future. It was built by a US industrial contractor and will carry experiments from four English universities under the direction of the British National Committee on Space Research of The Royal Society. The satellite will weigh 150 pounds and will carry experiments to investigate galactic noise, atmospheric ozone, and micrometeoroid flux. The UK 3 will be completely built and instrumented in Great Britain. The spacecraft will resemble the earlier UK satellites and will carry five experiments from British government and educational institutions. Launch is set for 1967. The Canadian Defence Research Telecommunications Establishment plans to continue to explore the upper atmosphere by radio means with a second Alouette satellite to be launched in 1965 and three ISIS (International Satellite for Ionospheric Studies) spacecraft. The ISIS series will be conducted in the 1967-69 period to provide detailed data on the ionosphere.

Italy also is planning to orbit scientific satellites with NASA's cooperation. Under Project San Marco, the University of Rome's Aerospace Research Center expects to orbit two test satellites this year, and then to launch an operational satellite weighing 250 pounds from a mobile launch plat-



The UK-2 satellite, built to carry experiments from four English universities, was conceived as a joint project of the United States and the United Kingdom.

form in the Indian Ocean off the east coast of Africa. Use of a launch site near the equator will permit, for the first time, an orbit only slightly inclined to the equator to allow direct and continuous measurement of the upper atmosphere above the equator.

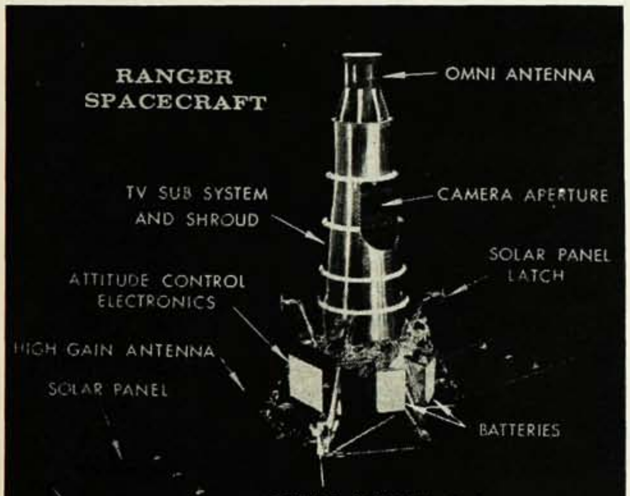
A French satellite, FR 1, will also be launched by NASA. The spacecraft will weigh about 200 pounds and will be used to study wave propagation at very low frequencies in the ionosphere. The French National Center for Space Studies plans to follow FR 1 with five additional satellites to be launched with their own boosters.

Lunar Probes

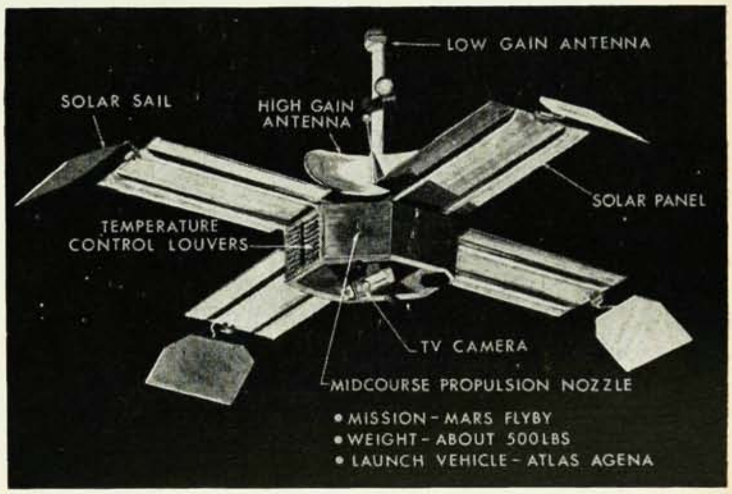
Although the principal emphasis of the unmanned lunar program has been shifted to support Project Apollo, much useful scientific data is expected to result. The recently reduced Ranger program will send three more spacecraft to the moon, each carrying a six-camera television package to provide close-up photographic coverage of the lunar surface. The payloads, weighing 375 pounds and mounted on the standard hexagonal Ranger spacecraft bus, will consist of two wide-angle cameras, four narrow-angle cameras, a control programmer, camera sequencer, telemetry system, two-channel transmitting system, and power supply. The camera payload will function during the last ten minutes of the flight as the 800-pound Ranger descends toward a lunar hard landing. The cameras will look down the descent path and provide an overlapping series of pictures converging toward point of impact. The wide- and narrow-angle camera systems will be redundant and will transmit pictures simultaneously over separate frequencies up to the time of impact.

The Surveyor program is intended to soft land a total of seven spacecraft (four test and three operational missions) on the moon beginning in 1965. Each spacecraft will weigh 2100 pounds when injected into lunar trajectory and should weigh about 600 pounds when it reaches the moon, including 114 pounds of scientific experiments. Surveyor will land on three legs tipped with crushable polystyrene pads and will stand eight feet high with a solar panel and high-gain directional planar antenna mounted on top. The solar panel will provide about 60 watts, and silver-zinc batteries will provide power through the lunar night. Landing will be planned for near mid-lunar day to enhance photography during the landing sequence and to permit completion of certain experiments before nightfall. Surveyor is designed to operate for at least thirty days, the equivalent of a lunar day and night. Solar and star sensors, gyros, nitrogen jets, three vernier engines, marker radar, and a solid-propellant retrorocket will be employed for mid-course corrections and descent to the moon after a 66-hour flight. The retrorocket will burn out at 28 miles above the lunar surface, and the spacecraft will be controlled by the vernier engines to an altitude of 13 feet at 5 to 20 fps; then all engines will cut off and Surveyor will drop on the moon. One television camera, pointing down the descent path and including a landing leg in its field of view, will take pictures from 1000 miles down to the surface. The scientific payloads for various soft landers will include two top-mounted TV cameras, soil-mechanics experiment, micrometeoroid-ejecta detector, and soil-analysis group, including a surface sampler, sample processor, x-ray diffractometer, and alpha-particle scattering device. Development of an unmanned roving vehicle to be landed on the moon by Surveyor is currently under consideration. The vehicle would operate in a two-mile diameter circle around the spacecraft, and would map the lunar surface and provide data on the load-carrying strength of the surface.

Work was recently initiated on a Lunar Orbiter, with a total of five spacecraft scheduled to be placed in orbit around the moon starting in 1966 to provide closeup photographic coverage. The photo-reconnaissance spacecraft will be three-axis stabilized and will be orbited down to within 22 miles of the lunar surface to take medium- and high-resolution pictures. In addition to topographic data yielded by the photographs, long-term tracking of the 800-pound lunar satellite will provide information on the moon's gravitational field and its mass distribution. The Lunar Orbiter will also be instrumented to measure lunar radiation and micrometeoroid density.



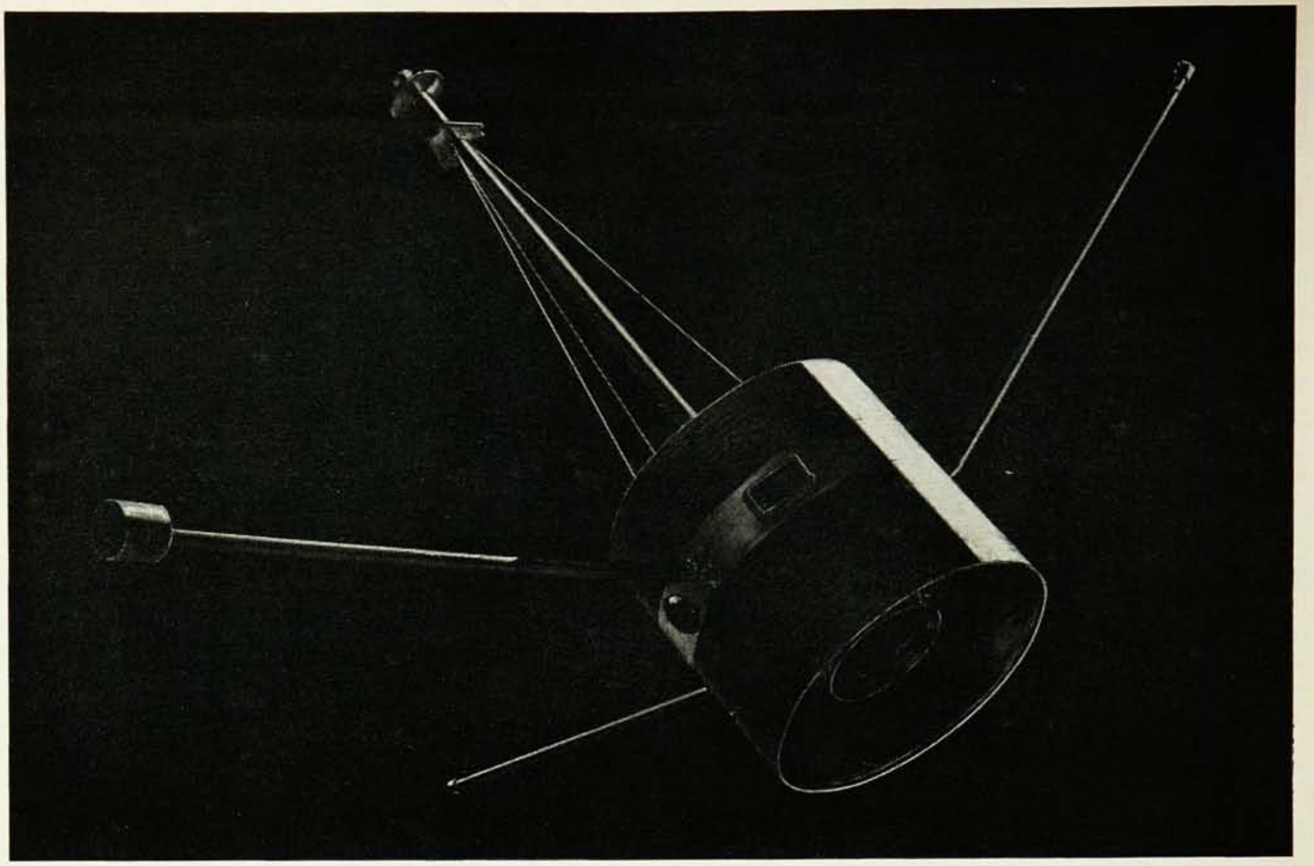
Ranger spacecraft has six TV cameras to provide closeup view of lunar surface in final moments before hard landing on moon. The fourteen flights originally planned under the Ranger program were reduced to nine after five successive failures. Ranger 6, representing a revised design, was launched early this year, but failed to transmit pictures.



The Mariner planetary probe, which also carries television equipment, will be launched late this year and is to be sent to the vicinity of Mars.

Planetary and Interplanetary Probes

The next series of two Mariner planetary probes will be launched in the last quarter of 1964 on Mars trajectories designed to produce a planetary flyby after a flight of approximately 230 days. Ideally, the spacecraft will pass within 13 500 miles of the illuminated side of Mars, returning data from ten experiments during a twenty-minute period. Experiments, both planetary and interplanetary, include a television camera, helium va-



Pioneer interplanetary probe to be placed in solar orbit during the IQSY.

por magnetometer, cosmic-dust detector, cosmic-ray telescope, and ultraviolet photometer. An important objective of the flights will be to determine if life exists on Mars.

Mariner will weigh around 570 pounds. Four solar panels, with solar pressure vanes at the end of each panel, will be attached to the basic octagonal structure. The television and ultraviolet photometer experiments will be mounted on the underside. A four-inch tube will extend through the top of the spacecraft to house the magnetometer and ion chamber, plus the low-gain antenna. The elliptical high-gain antenna will also be located on top. Attitude-control data will be supplied by two sun sensors and a star tracker using Canopus as its reference. One primary midcourse correction will be programmed, with a backup maneuver available if required.

The Pioneer program, inactive since the highly successful flight of Pioneer 5 in 1960, will provide a series of four interplanetary probes to be placed in orbit around the sun. The first launch in the new series is scheduled for 1965 in conjunction with the International Quiet Sun Years, with additional flights at six-month intervals. Specific objectives of these solar satellites will be to provide, together with other spacecraft, simultaneous measurements at widely separated points in interplanetary space. Each spacecraft will carry a thirty-pound scientific payload with as many as seven experiments to provide data on the interplanetary magnetic field, radio-propagation effects of the "quiet sun", plasma spectrometry, ionization levels, and solar, high-energy, and medium-energy particles. Pioneer orbits will range within 0.8 to 1.2 AU of the sun, and both elliptical and circular orbits will be employed.

The spin-stabilized spacecraft will be a 130-pound cylinder, 37 inches in diameter and 32 inches long. A high-gain antenna will extend from one end, and three stabilization booms will be projected from the midsection of the cylinder, with a magnetometer mounted on the end of one boom. A gas-jet attitude-control system, with input from four sun sensors, will orient Pioneer's longitudinal axis normal to the ecliptic plane. Electronic subsystems and most experiments will be mounted on a circular shelf about the center of the spacecraft, with thermal louvers set beneath the shelf to hold the internal temperature within ± five degrees. Pioneer's power will be supplied by 10 000 solar cells mounted on the cylinder.