Cover: Apollo 12 astronaut on the lunar surface removing parts of Surveyor III spacecraft. Surveyor's camera, soil sampler, a strut, and a piece of cable were brought back to earth for inspection by JPL scientists.
A description of work accomplished under Contract NAS 7-100 between the California Institute of Technology and the National Aeronautics and Space Administration for the period January 1, 1969, to December 31, 1969.

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The year 1969 climaxed the nation's first decade in space on a note of high achievement: the dramatic missions of Apollo XI and XII, the scientifically productive flights of Mariner VI and VII to Mars, and the recovery of Surveyor III artifacts from the surface of the moon.

Completing its thirtieth year, the Jet Propulsion Laboratory continued its support of unmanned planetary operations, contributed to the successful culmination of the Apollo program, and engaged in research and development activities ranging from space-associated science and technology to studies of transportation, urban crime, environmental pollution, and medical instrumentation problems.

The year also marked the inauguration of a new President of the California Institute of Technology. Dr. Harold Brown replaced Dr. Lee DuBridge, who retired after a 22-year incumbency to become Science Advisor to the President in Washington.

During 1969, the Visiting Committee began its function of advising the JPL Director in problems relating to general management, technical programs and external relations. A Radio Astronomy Experiment Selection Panel was also instituted, consonant with a program to use the facilities of the Deep Space Network in ground-based radio science projects on a non-interference basis. This panel comprises a group of distinguished scientists who will assist in selecting appropriate experiments in radio astronomy for periods of availability of DSN antennas.

During the year, the Laboratory also achieved significant improvement in its relationships with the university and scientific communities. In addition to the Resident Research Associate Program and the Summer Faculty Fellowship and Hiring Programs, the Caltech President's Fund and the JPL Director's Discretionary Fund were used to support this effort. The President's Fund, a combined NASA-Caltech program, provides support for research of interest to JPL and is implemented through academic institutions. The Director's Discretionary Fund provides further support to university research in fields of interest to the Laboratory and to NASA.

With the conclusion of the first decade of space research, the Jet Propulsion Laboratory looks forward to continuing participation in the exploration of both the near and the outer planets during the 1970's. This on-going program, coupled with an expanding involvement in urban, environmental, and social projects, promises a challenging future for JPL.
The first attempt to fly two spacecraft past a planet with encounter times only days apart was successfully completed by Mariner VI and Mariner VII in late summer of 1969. The Mariner Mars 1969 mission was designed to explore Mars from a flyby altitude of about 2000 miles, extending the findings of Mariner IV (1965) and providing data to form the basis for future missions—particularly with respect to the search for extraterrestrial life.

One spacecraft was launched in February and one in March 1969, and both were maneuvered to trajectories that were to bring them to the desired flyby altitude above Mars in late July and early August. An early decision had been to carry only Mars-oriented experiments and not to include interplanetary measurements. Each spacecraft was equipped with two television cameras, one wide-angle and one narrow-angle; two spectrometers, ultraviolet and infrared, and an infrared radiometer. These instruments were mounted on a movable scan platform to allow accurate pointing. Control of the spacecraft operations was enhanced by an on-board computer that could be reprogrammed in flight by commands from earth. This allowed the engineer-scientist team in charge of the mission to make last-minute changes in operation to obtain the most valuable data return.

Two tape recorders were carried to store the large amount of scientific data acquired by the instruments, and an experimental high-rate telemetry link (16,200 bits per second versus 8½ in 1965) was used for the first time in this mission. In addition, S-band occultation and celestial mechanics experiments were conducted, as in prior Mariner missions, without special flight instrumentation.

A number of unexpected events occurred en route and near the planet, but the flexibility designed into the spacecraft, coupled with the skill of the operators controlling the spacecraft from the ground, permitted adjustments to be made that resulted in successful completion of the mission.

The acquisition of science data took place in two phases for each spacecraft—far-encounter and near-encounter. Mariner VI and Mariner VII together spent a total of 5 days taking pictures at long range as they approached the planet; each day's recorded pictures were played back at the 16,200 bit-per-second rate to the 210-foot antenna at the Deep Space Network's Goldstone, California complex.

For about 1½ hour at the shortest range of near encounter, each spacecraft pointed its instruments at various regions on Mars to obtain upper-atmosphere ultraviolet spectra, lower-atmosphere and surface infrared spectra, overlapping wide- and narrow-angle television pictures, and a surface-temperature map. The temperature map followed a trace...
Opposite: South polar cap of Mars photographed by Mariner VII from an altitude of 3300 miles. Photograph covers an area of approximately 740 x 930 miles.

Right: Mariner Mars 1969 spacecraft.

Joining the centers of the pictures and extending beyond the sunlit surface (as did the spectrometer traces) onto the night side of the planet. Ultraviolet spectra were acquired every 3 seconds, infrared spectra every 10 seconds, and radiometer measurements every second.

Mariner VI, viewing the equatorial regions including Meridiani Sinus, obtained 25 near-encounter pictures; Mariner VII, whose scan started in the Meridiani Sinus region and moved south to include the south polar cap and the bright circular desert, Hellas, returned 33 pictures.

If anything, Mariner VI and VII found the environment existing on Mars more hostile to life as we know it than previous data had indicated. Atomic hydrogen and oxygen were detected in the outer atmosphere as expected. Carbon dioxide, carbon monoxide, a trace of water vapor, and both ice and dry ice clouds were found in the lower atmosphere, as well as possible indications of suspended particulate silica or silicate "dust" clouds. Ozone, nitrogen, and organic vapors such as ammonia and methane were not found.

Data from the S-band occultation experiments showed that the atmospheric pressure varied at the four occultation sites, being from 0.4% to 0.7% of that found at sea-level on earth.

From radiometer data, which indicated a very low temperature, and from its physical characteristics as shown in the television pictures, the south polar cap appears to be primarily frozen carbon dioxide.

Impact craters resembling those on the moon cover a large part of the area photographed at close range, including the south polar region; the Hellas area, however, is featureless, as though some process were at work which obliterates the crater fields as rapidly as they are formed. In the upper Pyrrhæa region, examples of a new form of terrain were photographed consisting of a jumbled array of hills and ridges. These could have been formed by slumping after the withdrawal of a subsurface material such as permafrost.

The data acquired by all instruments have proved so extensive and contain so much information that computer processing and intensive analysis will be required to interpret them.

From the results of the analysis to date, it may be concluded that Mariner VI and Mariner VII found nothing to confirm—or conversely, to explicitly deny—the possibility of life existing on Mars. No new evidence was found to contradict previous viewpoints held of Mars that stemmed from earth-based observations and the Mariner IV flyby; rather, the missions served to extend and verify the earlier conclusions.

In summary, it may now be concluded from the results of the Mariner VI and VII missions that, with respect to life on Mars,

1. The environment rules out any likelihood of Mars harboring life forms dependent upon atmospheric oxygen.
2. The environment might sustain low-order forms of life, e.g., certain types of microorganisms that have adapted to the severe Martian environment; such forms would, however, have had to evolve to accommodate to the small amount of water (vapor or liquid) available at the surface, the virtual absence of atmospheric oxygen, and the strong ultraviolet flux reaching the surface.

The two Mariner spacecraft continue to be operational and are in orbit about the sun, although the battery aboard Mariner VII is no longer functional.
A new experiment testing the ability of general theories of relativity to predict orbital precession is planned to take advantage of certain characteristics of the Mariner 1969 extended mission. This experiment, made possible through use of the advanced antenna system at Goldstone and the improved design features embodied in the spacecraft, is based on the promise of two-way tracking and turnaround ranging to distances much greater than previously possible. The trajectories will bring the spacecraft within a close angular range of the sun and, through extended tracking and ranging, define the spacecraft orbits very precisely. Ranging passes near solar syzygy will be used to measure the delay in the ranging signal caused by the solar gravitational field. In this way it may prove possible to test which general relativity theories predict the relativistic effect on the motion of the spacecraft and on the radiation used in ranging.

MARINER MARS 1971

During the past year, the mission planning and the spacecraft design for the Mariner Mars 1971 project were completed and all major hardware procurements were initiated. Breadboard and prototype spacecraft hardware were undergoing tests. Mission operations were being planned, computer programs developed, and test schedules formulated.

The mission plan provides for two identical spacecraft to perform separate but complementary missions. Each spacecraft will orbit Mars for about 90 days. Mission A, with an earth-synchronous 12-hour orbit, is basically a reconnaissance mission to view 70% of the Martian surface with the highest resolution possible. Mission B, with a 32.8-hour Mars-harmonic orbit, is designed to study the time-variable features of the Martian atmosphere and surface.

The orbit for Mission A will extend from a low point of 1000 miles to a high of 10,500. The orbital period of 12 hours will be timed to allow coverage, on every other orbit, by the Goldstone 210-foot antenna, which is capable of receiving data from the spacecraft at 16,200 bits per second. Synchronizing the orbit to the Goldstone view period will permit daily transmission of
scientific data. The orbit of Mission B, with a low point of 1000 miles and a high of 27,000, will be designed to repeat coverage of selected areas throughout the mission to permit studying changes on the surface as they occur over the 90-day mission period.

Six experiments will be performed during each mission: (1) visual imaging, using the television cameras, (2) ultraviolet spectroscopy, (3) infrared spectroscopy, (4) infrared radiometry, (5) S-band occultation, and (6) celestial mechanics. The last two experiments use the spacecraft radio link and do not require special instruments aboard the spacecraft.

The 1971 spacecraft will be similar in design to Mariner VI and VII; however, a retro-engine will be added to insert the spacecraft into Martian orbit. The engine will contain 900 pounds of propellants, providing the capability of making five mid-course and trim maneuvers and a velocity change of 5000 feet per second for orbital insertion.

Each spacecraft will weigh approximately 2200 pounds and will be launched by the Atlas/Centaur in early spring of 1971 to arrive at Mars in mid-fall.

VIKING ORBITER

The Viking Project was initiated by NASA late in 1968. The Project, managed by the Langley Research Center, has as its objective two missions to orbit and land on Mars.*

The Viking missions will utilize data from the 1965, 1969, and 1971 Mariner flights. The Mariner Mars 1971 orbiters, which will provide the first extended surveillance of Mars from spacecraft, will furnish data to assist in selecting sites for the Viking landers.

The Viking Project represents a significant step in the exploration of Mars by providing, in addition to measurements from the orbiter, scientific experiments from the lander as it passes through the Martian atmosphere and rests on the surface.

The two spacecraft will be launched separately on Titan/Centaur launch vehicles. The Titan and Centaur have not previously been used in combination, and their integration is currently in progress by joint agreement of NASA and the Air Force.

The lander is being developed for Langley by the Martin Marietta Corporation, Denver, Colorado. The development of the orbiter, spacecraft navigation, and the tracking and data acquisition are responsibilities assigned to JPL. JPL is also developing the gas chromatograph/mass spectrometer, which will perform organic analysis of the surface of Mars.

Prime functions of the orbiter are to provide site surveillance data to be used in the selection of the exact landing sites, and

*As originally planned, two launches were scheduled for mid-1973; however, in January 1970, NASA postponed the dual mission until the late summer of 1975, with arrival at Mars approximately 1 year later.

Top: Viking orbiter.
to deliver the lander into orbit and support the lander mission. It will also serve as a relay station to record and transmit to earth data received from the lander during entry and after landing. When the orbiter is not serving as a relay, it will perform science experiments. A 90-day lifetime for both the orbiter and lander, following their separation in orbit, is planned.

Science experiments to be included on the orbiter are visual imaging of the surface, infrared radiometry to obtain radiation temperature data from the surface, infrared spectrometry to determine the distribution and abundance of water vapor, and radio experiments to obtain data that will improve planetary navigation capability and provide measurements of radio propagation properties and Mars atmospheric data.

**MARINER VENUS–MERCURY 1973**

Project management responsibility for the Mariner Venus–Mercury 1973 Project, initiated by NASA in late 1969, was assigned to JPL.

A single mission, to be launched in the fall of 1973, has as its primary objective exploratory investigations of the environment, atmosphere, surface, and body characteristics of Mercury. Interplanetary experiments are also planned. The trajectory provides for a close flyby of Venus to acquire experience with a gravity-assist mission and to obtain atmospheric data concerning Venus to supplement that obtained during the 1962 and 1967 Mariner missions. Passage of Venus will occur in early February 1974 and the Mercury flyby in late March. Mariner 1973 will be the first dual-planet and gravity-assist type of mission as well as being the first flight to Mercury.

Mission planning is currently in progress, and a Science Steering Group has been established by NASA to assist the JPL mission design team in formulating a baseline design. Maximum utilization of the Mariner Mars 1969 and the Mariner Mars 1971 subsystem designs is planned in the interest of minimizing the total project costs. Current plans provide for implementation of the project by utilizing a systems contractor working under JPL direction to develop, assemble, and test the spacecraft system and operational support equipment.

**FLIGHT SCIENCE EXPERIMENTS**

Flight science involves the development of hardware for and conducting of science experiments from non-JPL spacecraft. Significant new activities or scientific findings in this area are outlined below.

**Lunar Orbiter Missions**

Analysis of tracking data from the five Lunar Orbiter spacecraft launched by the Langley Research Center showed the moon to contain high-density regions, as evidenced by the mascons (mass concentrations) associated with the ringed maria. Large-scale density variations are also indicated by the results of an harmonic analysis of the data. In addition to the large, second-degree terms known prior to the Orbiter flights, there are large terms of higher degree. A dynamic determination of the surface mass distribution was made in cooperation with the Aerospace Corp. The results are interpreted in terms of low-gravity rings around the mascon basins and areas of higher gravity which correlate with the locations of ejecta from the impact basins. These results were used in Apollo navigation.

**Apollo Missions**

During 1969, JPL was invited to participate in the Apollo laser ranging experiment designed to measure the earth–moon distance with extreme precision. Reflector arrays are deployed on the lunar surface, laser beams are fired at them from the earth, and the transit time of the light beam to the moon and back is measured. These transit times are expected to yield information on the lunar motion and on earth processes such as polar motion, continental drift, and solid body tides.

Initial observations using the reflector array deployed by the Apollo 11 astronauts were made at the Lick Observatory (Mt. Hamilton, California) on August 1, 1969, with residual errors of up to 300 meters with respect to the JPL predictions, and at the McDonald Observatory (Ft. Davis, Texas) on August 20, 1969, with a residual of 38 ±8 meters. Subsequent analysis revealed that the Lick residuals were largely due to an error in the location of the observatory. A computer program was developed and predictions were computed on a continuing basis.

The JPL solar wind spectrometer (SWS) was successfully placed on the lunar surface by Apollo 12 astronauts on November 19, 1969. The instrument is designed to measure the direction, magnitude, and intensity of the solar plasma flux reaching the moon. All data obtained to date indicate that the instrument is performing perfectly. It is intended to remain in operation up to a year. An identical SWS is planned to be flown on Apollo 15 for a second experiment in the latter part of 1970.

During the past year, a gamma-ray spectrometer was designed for three lunar flights, beginning with Apollo 16. Instrument development has proceeded to the completion of a qualification test unit. The spectrometer will measure natural and cosmic-ray-induced gamma-ray flux in the 0.1 to 10 million-electron-volt range from the orbiting command service module. The experiment will estimate the degree of chemical differentiation of the moon and map compositional differences between large-scale features.
Biosatellite D Mission

In late June, Biosatellite D was launched from Cape Kennedy with a monkey aboard for the purpose of studying the effect of weightlessness on a primate. Among other experiments, the satellite carried a urine analyzer developed at JPL to detect the concentration of creatine-creatinine and calcium in the urine, as indicators of the monkey's muscular and skeletal condition. The instrument operated properly for the duration of the 8-day mission. Implications of the experiment are still being evaluated.

OGO Mission

Analysis of data obtained from the search coil magnetometer launched on Orbiting Geophysical Observatory (OGO) VI in June of this year is continuing, following the completely successful operation of the instrument.

Nimbus E Mission

A five-channel microwave radiometer is being designed and built for a meteorological experiment selected for the Nimbus E satellite. By analyzing the data from the instrument, the atmospheric temperature profile and water content can be obtained, even in the presence of moderate cloud cover. This is an important and necessary part of the information needed by meteorologists for long-range numerical weather forecasting on a global scale.

ADVANCED PLANETARY MISSIONS TECHNOLOGY

During 1969, the Advanced Planetary Missions Technology (APMT) Program continued to provide support to the Laboratory and to NASA in the evaluation, definition, and planning of potential planetary programs.

In support of the Planetary Exploration Planning Panel, 90 synopses were prepared for five groups of missions: a Balanced Base Program, a Mars Emphasis Program, a Mars Manned Support Program, a Venus Emphasis Program, and an Outer Planets Program. These missions include flybys, orbiters, probes, landers, and multiple planet missions, as well as comet and asteroid missions. The synopses present scheduling and resource estimates, with an indication of the validity of each synopsis based on the amount of study and review received.

Continuing into the early part of 1969, planning for the Viking 1973 project was carried out in cooperation with the Langley Research Center. Areas of planning in which the APMT Office participated included the baseline orbiter design, overall mission design, the preparation of the Viking initial mission definition, and the formation of the science instrument teams for the lander portion of the mission.

A detailed study of a mission to Mercury in 1973, using a gravity assist at Venus, was initiated in late 1968. The mission study was completed in summer, and the members of the science instrument teams were chosen.

In response to a request from NASA, the APMT Office conducted studies of possible missions to the outer planets. The proposed missions were a 1974 Jupiter flyby, a 1977 Jupiter-Saturn-Pluto flyby, and a 1979 Jupiter-Uranus-Neptune flyby. These survey missions would be followed by a Jupiter flyby/entry probe, a Jupiter orbiter, and Saturn and Uranus flyby probes.

Subsequent considerations by NASA led to the deferral of the 1974 Jupiter flyby and, in order to maintain a balanced Outer Planets Exploration Program, a study is being made of the feasibility of a Jupiter orbiter mission in 1975. According to an earlier study of a 1980 Jupiter orbiter, a 1975 flight appears feasible but may be somewhat marginal if launched on a Titan III-D/Centaur/Burner II vehicle combination. The availability of the Titan III-F/Centaur would improve the picture considerably.
OPERATIONS

The Deep Space Network (DSN) closed the decade with one of the busiest years since its establishment nearly a dozen years ago. During 1969, the Network provided tracking and data acquisition support for the dual-spacecraft mission of Mariner VI and Mariner VII to Mars and the launch of Pioneer E. DSN facilities around the world were utilized in joint operation with the NASA Manned Space Flight Network (MSFN) in support of the manned flights of Apollo 9, 10, 11, and 12. Extended mission activity continued with Pioneer VI, VII, VIII, and IX. Planning was initiated for DSN support of a proposed dual-planet mission to Venus and Mercury, and the Pioneer F and G flights to the vicinity of Jupiter. DSN flight project interfaces were defined as part of the continuing preparation for Mariner Mars 1971, Viking Mars, and Helios, a project of NASA and the West German government.

MARINER VI AND VII

The Mariner VI and Manner VII Mars exploration missions provided the DSN with one of the most thorough in-flight tests possible—that of checking out the new high-rate telemetry system. A research and development project designed for future missions, the high-rate telemetry system proved capable of processing video data at a rate of 16,200 bits per second (86,400 symbols). The two spacecraft encountered Mars five days apart last July and August, and returned approximately 200 high-quality pictures of the planet. On-board magnetic tape recorders, both analog and digital, were used to store the pictures for retransmission at both 16,200 and 270 bits per second. Use of the high-rate telemetry system allowed playback of a full tape load—33 pictures—in about 2½ hours and permitted the recording and transmission of full Mars view pictures at brief intervals several days prior to encounter.

The DSN provided emergency support when the radio signal from Mariner VII disappeared just a few hours before Mariner VI was to make its closest approach to Mars on July 30. During a 7-hour period in which the fate of the spacecraft was not known, virtually every station in the Network was involved in either the crucial encounter operations of Mariner VI or the search for Mariner VII. The signal was reacquired and, after a series of ground commands, Mariner VII successfully completed its mission.

The Compatibility Test Area (CTA 21), designed to establish compatibility between the spacecraft telecommunications equipment and elements of the DSN, was used in a variety of functions during the encounter phase of the Mariner VI and VII flights. High-rate video data received by the 210-foot antenna at Goldstone, California, were microwaved to CTA 21 at JPL, where they were processed and sent to the Space
Flight Operations Facility (SFOF) for computer processing, scan conversion, and real-time display for operations personnel and public information activities.

Two Mariner experiments—S-band occultation and celestial mechanics—used the communications link between the spacecraft and the ground stations of the DSN as the prime mechanization of the experiments. The extremely sensitive receiving equipment provided data that yielded the pressures and densities of the Martian atmosphere. From variations in the frequency of the Mariner radio signal as it penetrated the atmosphere and was cut off (occulted) from earth, it was determined that Mars’ surface pressure is between 6 and 7 millibars, or less than 1/100 that of earth. The radiometric data obtained during the entire flight were used for the celestial mechanics experiment and will provide information to refine astronomical data.

The two-spacecraft mission constituted the second successful U.S. exploration of Mars and the fourth flight to another planet in less than 7 years.

PIONEER EXTENDED MISSION

The DSN continued the regular tracking and data acquisition support of the still-active Pioneer VI, VII, VIII, and IX missions. Pioneer VI and VII were tracked by the 210-foot-antenna station at Goldstone; the 85-foot-antenna station in South Africa, Spain, and Australia supported Pioneer VIII and IX. The total Pioneer support during the year was approximately 12,000 hours, during which time the DSN collected over 3.5 billion bits of telemetry data containing information on fields and particles, thus further defining the solar environment. This information was collected by more than 20 scientific instruments carried by the four Pioneers, traveling in the ecliptic plane. The telemetry data also contained engineering measurements made on board the spacecraft which were necessary to maintain the earth-controlled housekeeping functions. The Flight Operations Team of the Pioneer Project was able to control the four Pioneers in a near-optimum configuration by sending 9200 commands to them.

By making certain improvements in the S-band receiver, the DSN was able to extend the planned support of Pioneer IX on the 85-foot antennas from May until December 1969.

The DSN gave a dynamic demonstration of advanced capabilities of the 210-foot-antenna station on November 29, 1969, when both the Pioneer VI and VII spacecraft signals were received within the 0.15-degree beamwidth of the 210-foot antenna and the telemetry signals of both spacecraft were simultaneously detected, displayed, and recorded.

During the year, the DSN also supported the planning, testing, and launch preparations of the Pioneer E mission. The space-
The Apollo 11 mission was the historic first manned lunar landing on July 20 on the Sea of Tranquility; and Apollo 12, the exceptional navigational feat that landed the astronauts on the Ocean of Storms just a short moonwalk from its target, the Surveyor III spacecraft.

Three of the DSN's 85-foot-antenna stations—at Goldstone, California; Madrid, Spain; and Canberra, Australia—are equipped with Manned Space Flight Network control room wings to support MSFN prime stations. All three, along with the 210-foot-antenna station at Goldstone and the Cape Kennedy station, were on line for the Apollo 10, 11, and 12 flights. For the Apollo 10 earth orbital mission, the Cape Kennedy station supported prelaunch and launch operations and the Canberra station was called upon to participate in the rendezvous and docking phase.

Real-time color television was transmitted from the moon for the first time during the Apollo 10 mission. Nineteen color TV transmissions totaling nearly 6 hours were received at MSFN and DSN stations. Most of the TV activity occurred during the Goldstone view period.

On the Apollo 11 mission, the Manned Spacecraft Center delayed the lunar module descent from the thirteenth to the fourteenth lunar orbit so that the descent would take place during the Goldstone view period. It was decided to take advantage of the receiving capability of the 210-foot antenna, which could provide high-bit-rate telemetry via the LM omni antenna as a backup in the event of data dropouts from the LM's steerable high-gain antenna.

For the lunar flights, the Goldstone Standards Laboratory provided a traveling cesium clock to synchronize the clocks at all the participating stations prior to, during, and after the missions.

FACILITY MODERNIZATION

A contractor was selected in June to build two 210-foot-diameter antennas to be installed near Canberra, Australia, and Madrid, Spain. Site development at both locations continued during 1969, and construction began at Canberra in December. With the existing advanced antenna at Goldstone, the new antennas will complete a subnetwork of 210's. Development and installation of the large antennas is part of the continuing long-range effort to extend the technical capability of the DSN in keeping with spacecraft communications re-
Opposite: The original 210, Mars station, Goldstone, California.

requirements. The network of 210's, to be operational in 1973, will be a major element of the Mark III Deep Space Network, a tracking and data acquisition system with the objectives of providing continuous coverage for planetary spacecraft; providing increased data flow from spacecraft to ground; enabling high-power, positive command control; extending the useful life of planetary and interplanetary spacecraft, allowing greater complexity of science experiments; and permitting simpler spacecraft design.

The emergency power subsystem for the Space Flight Operations Facility nearing completion at the end of 1969. The new power house, located adjacent to the SFOF building, represents the first major modification to the SFOF electrical system since the facility was constructed more than five years ago. Heart of the emergency power subsystem is the uninterruptible power system (UPS). The UPS converts alternating current to direct current, which charges batteries and powers inverters. Reliability of the UPS is predicted at 80,000 hours, or about 9 years, mean time between failures.

Power supply for a 400-kilowatt S-band transmitter for the 210-foot antenna has been installed in the new transmitter building at the Goldstone Mars site. The transmitter itself is being prepared for installation early in 1970. A similar transmitter has been in operation at the Venus site since 1968. High-power transmitters are planned for all 210-foot antennas in the network in the mid-1970's.

RADIO SCIENCE SUPPORT

In testing, developing and demonstrating new systems for the DSN, use was made of the Venus development station and the Mars 210-foot-antenna station in conducting several bistatic planetary radar experiments. In particular, range-doppler mapping on Venus disclosed a bright, round feature in the place where feature Alpha was located on spectra taken in 1964. A series of ranging experiments improved our knowledge of Venus' orbit, radius, and shape. A Mars experiment revealed height differences near the equator of that planet; in addition, improved estimates of the Mars ephemeris and radius were obtained in time to be used for the Mariner VI and VII encounters. The reflectivity characteristics of Mercury were determined, and several features were observed on the spectra.

A series of experiments was conducted at the Venus station to determine whether pulsars can be used as a time standard for the DSN. More precise estimates of the positions and periods of several pulsars were obtained, as well as more exact estimates of the rates of decay of their periods.

A solar corona occultation experiment was performed using the Pioneer VI spacecraft. Spectra taken show a pattern of broadening of the type that would be caused by solar flares.

A sequential decoder capable of operating at bit rates 10 times or more faster than the Mariner high-rate telemetry system was constructed. It was demonstrated using five telemetry from the Pioneer IX spacecraft, which has a convolutionally coded telemetry system. Bit rates in the upper end of the range of capability of the decoder are planned for the outer planet missions as well as the Mars high-rate telemetry orbiters.

A new fast-acquisition ranging system was demonstrated with the Mariner VI and VII spacecraft after encounters. This device uses sequential components instead of the parallel components of the previous design. In addition to the operational threshold being reduced, size, cost, and complexity also decrease. Furthermore, the system is capable of being automated to reduce ranging particle calibration time. It also provides an output giving differenced range versus integrated doppler for charged particle calibration. It has not failed to acquire the range code in over 30 Mariner tests. The fast-acquisition ranging system has therefore been adopted as the prime system for the Mariner 1969 extended mission.

In April, the Venus station received and recorded signals from several quasars which were relatively close to the sun.

Clock synchronization transmissions via moon reflection continued from the Venus station to receivers at the two Australian stations and to one of the stations in Spain. The Venus station clock is adjusted as required to keep within plus or minus 5 microseconds of the National Bureau of Standards' standard clock B.

Ranging data generated by the DSN during the tracking of Mariner VI and VII spacecraft was used to extend data through earth's ionosphere. To obtain data from which a reasonably accurate ionosphere model could be prepared, and from which corrections could be obtained for use with the ranging data, the Venus station monitored signals from Applications Technology Satellite 1 in synchronous orbit over Hawaii. Analysis of received signals will enable the measurement of Faraday rotation and subsequent application to ionosphere modeling.

The facilities of the DSN also were made available on a restricted basis to the radio astronomy and radio science community for experiments requiring the unique capability of the 210-foot antenna at Goldstone or the long baseline configurations in the DSN. Present schedules allocate 5% of 210-foot-antenna time to this activity. Recent radio science work using the 210 and other stations of the Network has been conducted by experimenters representing Harvard University, the California Institute of Technology, and the South African and Australian governments.
During 1969, research continued in the physical sciences, broadening our understanding of physical phenomena and providing a basis for future developments in various phases of space technology.

Low-Energy Electron Scattering
An experimental study of electron-N, scattering yielded the first complete set of absolute electron scattering cross sections for any molecule. These cross sections are needed to interpret many atmospheric phenomena. With the appropriate choice of impact energy and scattering angle, electron energy levels which are not observable in optical spectroscopy have been observed, some of them for the first time.

Ion Cyclotron Resonance Studies
The ion-molecule reactions of ions formed by electron impact in methane-ammonia mixtures were studied using ion cyclotron resonance. Experiments on mixtures of isotopically substituted methane and ammonia identified several proton and hydrogen atom transfer reactions, in addition to charge transfer and a condensation reaction between the fragment ion CH₃ and neutral NH₃. These studies are of considerable interest because of the presence of these molecules in the atmosphere of Jupiter.

Interplanetary and Solar Fluid Physics
In an experimental investigation of flow behavior at a magnetic X-type neutral point, a characteristic phenomenon of considerable significance to astrophysics was demonstrated. It was established that, providing (1) the flow has reasonable boundary conditions, (2) the flow is both supersonic and sub-Alfvénic throughout except near the neutral point, and (3) the electrical conduction mechanism is based on binary collisions, the critical magnetic Reynolds number becomes a decreasing function approaching zero in a finite time. This time development, however, is necessarily accompanied by increasing current concentration without compensating increase in plasma density. Consequently, before it can reach the hypothetical state of zero Reynolds number, the time development is terminated in a violent magnetic energy-releasing episode when carrier starvation causes the normal conduction mechanism to fail. In addition, the flow structure was found to include slow-mode hydromagnetic shock waves, such waves, whose existence has long been predicted theoretically, have not been identified before in laboratory experiments.

Relativity
Current research in general relativity has been concerned with the equilibrium states of strongly gravitating, steadily rotating, fluid objects. Several new exact solutions of the Einstein theory for such objects were found, and a general discussion of them is

Research and Advanced Development

Opposite: Soil samples being collected on volcanic Deception Island in the Antarctic. Samples are studied to determine the presence of microorganisms under extreme environmental conditions believed similar to those prevailing on Mars.
in preparation. It is hoped that this work can be applied to astronomical situations involving extreme gravitational fields, viz., pulsars and quasars.

Theoretical Physics
A self-consistent perturbation theory was developed for treating the electron-gas model of metals. The treatment yields a dielectric function for metals more accurate than any heretofore obtained and allows the effect of electron exchange on the dynamic screening in metals to be obtained. The theory will be applied to the calculation of such quantities as specific heat, effective mass, and magnetic susceptibility.

Polymer Research
A search for polymers with a well established structure and high electronic conductivity led to a study of the Menshutkin reaction involving difunctional amines and halides. This study resulted in a synthesis of several new families of polyelectrolytes termed ionene polymers. Their structure was elucidated using nuclear magnetic resonance spectroscopy and chemical kinetics. Ionene polymers may be obtained in the form of crystalline powders or elastomers. The former have bacteriostatic, fungicidal, and flocculating properties and therefore may find a variety of applications, including the purification of brackish waters. The elastomers yield nonthrombogenic surfaces and electrically conducting rubbers.

Pumping Mechanisms in a Carbon Dioxide Laser
An experimental study was undertaken in FY '69 to determine the dominant excitation mechanisms in a pulsed carbon dioxide laser. In the course of the investigation it was found that the pumping rate of the upper level of the laser is a function of the recombination rate of carbon monoxide molecules with oxygen atoms to form excited carbon dioxide molecules. The latter subsequently decay and become the source for the laser pumping. It was also found that, by measuring the lag of the laser light pulse behind the discharge current, the formation rate of carbon dioxide could be determined free of any effects due to impurities such as water vapor, which usually make other measurements of this rate very difficult. An important outgrowth of this study is the discovery of a new way to measure gas kinetic recombination rates which is not affected by the purity of the gas used in the measurement. This technique will be used to measure recombination rates in gases such as hydrogen fluoride, where the effects of impurities normally make accurate measurements impossible.

Literal Series Expansions
Recent advances in high-speed digital computer capability, specifically the ability to do literal mathematics (i.e., manipulation of symbols), has opened the way for novel methods in applied mathematics research. Certain general problems can now be solved in analytical, rather than numerical, form by machine methods.

In the past few years, several "algebraic" programming systems or compilers have been designed, and about 40 algebraic programming languages exist. One of the best known is Formac (Formula Algebraic Compiler). However, Formac is extremely general and consequently it is not efficient in special problems. For this reason, a more specialized system for analytical series expansions on a computer is being designed and implemented: a Fortran 4 package for manipulation of Taylor series, Fourier series, and a combination of the two (Poisson series).

SPACE SCIENCES
Space science is that aspect of physical science devoted to the study of planetary, interplanetary, and solar phenomena and thus includes planetary astronomy as well as flight experiments. Current efforts are concentrated on developing both experimental and analytical techniques for determining planetary surface and atmospheric properties.
Radar image of the Badwater area in Death Valley is typical of data acquired during a flight test aboard the NASA-Ames Convair in May. The long-wavelength (25-cm) radar image (bottom) is compared with a photograph of the same region (top). The synthetic aperture radar is being developed for future spacecraft missions, particularly for exploring the surfaces of the moon and Venus; the resolution element is about 4 x 100 meters.

was designed and fabricated. The instrument measures the metabolic conversion of C14O2 into organic compounds in the Martian soil. Conversion is detected by pyrolysis of the sample, followed by selective filtering and radioactive assay of the filtered emitted gases.

Infrared Astronomy

In a continuing program of high-resolution investigations of planetary and stellar infrared spectra, the JPL, Connes-type, Fourier interference spectrometer was installed in January 1969 at the 107-inch reflecting telescope at McDonald Observatory (University of Texas). It has been used since then for investigations of Mars and Venus, and reduction and analysis of the resulting spectra are in progress. A joint program was begun in collaboration with University of Texas astronomers to observe cool stars, with resolution ranging from 0.2 to 1.0 cm−1.

Optical Astronomy

Proof of the existence of water on Mars was obtained this year when a series of very-high-resolution photographic plates was obtained at the McDonald Observatory 82-inch and 107-inch reflecting telescopes. These plates show unmistakable Martian water vapor lines, well separated from the earth-atmospheric water lines by the favorable doppler shift at the time of observation.

The data indicate that in February and March 1969, the northern hemisphere of Mars contained 26 ± 5 microns precipitable water and the southern hemisphere less than 10 microns. The time of observation corresponded to mid-summer in the Martian northern hemisphere, when the north polar cap was at its greatest rate of decline and the south polar cap was forming, although hidden from view beneath a dense polar hood.

Spectra of Mars were also obtained in August, at the time of the Mariner VI and VII encounters. Although the doppler shift was not as favorable, the spectroscopic technique was sufficiently sensitive to determine positively that the total water content in the Martian atmosphere was reduced by a factor of three to four. This condition persisted through October 1969.

Table Mountain Observatory

With a focal length of 15 feet, the Table Mountain Coudé spectrograph is the largest of its kind in the world. A 12 x 14 inch grating is being ruled with which spectra of Mars at 8000 angstroms, and a spectral resolution of 0.04 angstrom can be obtained in less than 2 hours, permitting such programs as the routine surveillance of the seasonal variation of the water content on Mars.

Radio Astronomy

JPL collaborated with five other institutions in the successful operation of a
very-longaseline (VLB) interferometer experiment employing the 210-foot antenna at Goldstone, California, and the 85-foot antenna at Tidbinbilla, Australia. The intercontinental baseline provided fringe spacings down to 0.001 inch at a wavelength of 13 centimeters. Sources studied included many quasi-stellar objects, several pulsars, and a number of galaxies. A panel has been formed for the purpose of selecting experiments to be performed using the Goldstone 210.

Bioscience

Organic analysis of the Pueblito de Allende meteorite, which fell in early 1969, indicates that a coal-like polymeric substance is the major organic constituent. Other investigations had shown the presence of minute amounts of extractable terrestrial contaminants; these were removed before the analysis, thus giving a high degree of confidence that indigenous material representative of cosmic organic matter had been characterized in the meteorite.

ELECTRONICS

Virtually every aspect of spacecraft technology either depends on or is influenced by the state of the art in electronics. Research and development in this area provide much of the forward thrust of space technology.

Magneto-Optic Information Storage

An experimental study of the growth of thin ferromagnetic films of manganese bismuthide (MnBi) has led to films with characteristics particularly suitable for laser recording. With the newer films, only tens of oersteds are needed to control flux reversal by the technique of Curie-point switching, as compared to hundreds of oersteds previously required. This is a significant development for the practical application of Curie-point switching as a recording technique.

Thermionics Research

The feasibility of using a cesium vapor thermionic diode as a power-conditioning switch for high-temperature power sources was demonstrated. Experimental results indicate that efficiencies as high as 85% may be obtained at 1500 hertz. The diode switch is promising for use in reactor thermionic generators because of its efficiency and its ability to operate in a high-temperature environment.

Parametric Amplifier Development

An all-solid-state parametric amplifier is being developed to provide reliable operation for long-life Grand Tour missions (up to 12 years). It must also be lightweight, small in volume, and require little dc power. The parametric amplifier design, including an X-band solid-state pump source, will utilize microwave integrated circuit technology on ceramic substrates.

Model of rotatable multi-cathode electron gun designed for extreme life capability.

Multi-Cathode Electron Gun

A rotatable model of a multi-cathode electron gun capable of replacing its own worn-out emitters was designed and tested. This concept was generated to solve the lifetime problems of electron tubes which will serve as transmitters on outer planet missions. Incoroporation of this design into actual working electron tubes is under way in anticipation of the mission requirements of the next decade.

Electronic Packaging

Thick-film hybrid technology development reached the point of fabrication of test units. This packaging technique incorporates screened and fired conductors and cermet resistors on an alumina substrate to which silicon semiconductors are added to complete the integrated microcircuit. The development is directed toward understanding the interaction of the design, materials, parts, and processes so as to assure the functioning of the electronic circuits in a defined environment for a specified lifetime.

GUIDANCE AND CONTROL

The objective of the current research and development program in guidance and control is to develop the capability for accurate navigation for outer planet missions. This represents a change in emphasis from the previous effort that was focused on the terrestrial planets.

Navigation and Guidance and Spacecraft Control

A planetary-approach navigation experiment using spacecraft-based sightings was performed successfully on the 1969 Mariner mission to Mars. During the last few days before encounter, each Mariner spacecraft transmitted to earth television pictures of Mars from the narrow-angle science TV camera, and measurements of the camera pointing direction and spacecraft attitude. These data were processed to give the direction of Mars as viewed from the spacecraft and then combined with earth-based data to estimate the trajectory of each spacecraft in relation to earth and Mars.
during flight operations. The experiment represented the first attempt to use data obtained from sensors on board an interplanetary spacecraft for the purpose of navigation. The results will be valuable for future missions to more distant planets, for which accurate navigation may require spacecraft-based measurements.

Interaction of Flexible Structures

Significant progress was made in the development of analytical techniques to study the interaction of flexible structures on spacecraft-flight-control systems. Missions to the outer planets will be performed by vehicles with flexible antennas and booms coupled with momentum wheel control systems. Since ground testing for these vehicles is not feasible, accurate analytical techniques will be required. A new hybrid-coordinate technique incorporating model analysis with rigid-body analysis was developed to meet future needs.

Control Theory Applications

Modern control theory (optimal control theory and dynamic programming) was applied to the design of a minimum-energy controller for an electric drive system. The original application was intended for a planetary surface roving vehicle, but the system design was sufficiently general that possible commercial applications might be considered. A laboratory demonstration breadboard was built and is operating successfully. Tests are now being conducted to evaluate the potential of the concept.

Self-Mode-Locking

In work leading toward a fast-response laser-ranging sensor, a helium-neon laser was reliably self-mode-locked without the need for an active mode-locking modulator. Mode-locking converts the otherwise continuous-wave laser light into a single pulse of about 5 x 10^-14 seconds duration, which propagates back and forth within the laser cavity. Studies are being made of the conditions necessary for stable self-mode-locking and of the supporting physical theory.

Strapdown Gyroscope System

The basic feasibility of a strapdown electrically suspended gyroscope aerospace navigation (SEAN) system was demonstrated. The system utilizes two electrically suspended gyroes in conjunction with a digital computer. It is unique among navigators in that it uses position gyros to provide attitude information.

Orbit Determination

A comprehensive analysis of orbit determination accuracies for missions involving a planetary orbiter indicates that orbit determination software using classical least-squares techniques is not adequate for a spacecraft in orbit about a remote planet. Problem areas, such as perturbation due to uncertainties in the planet’s gravity field and nonlinearities in the navigation and orbit determination processes, were isolated. New algorithms have been formulated and are being incorporated into the maneuver strategy and navigation analysis programs.

Location of Geodetic Control Points

JPL has been participating in the National Geodetic Society Program, which has as an objective providing geodetic control point locations throughout the world with an accuracy of 10 meters or better. One application from this effort will be providing a worldwide datum for use in the establishment of global navigation systems. During 1969, the Deep Space Network station locations were determined with uncertainties of less than 5 meters in both radius from the earth’s spin axis and longitude, in contrast to the uncertainties of 20 meters derived from analysis of tracking data from the Ranger missions and 10 meters available during the Mariner IV and V missions.

TELECOMMUNICATIONS

The steadily increasing capability in telecommunications, which made possible the high data rate for Mariner VI and VII, was used to support the Apollo 11 mission and to perform ground-based telemetry experiments on the inner planets. Telecommunications research and advanced development is now being focused on problems associated with high-data-rate communications with future spacecraft at the extremes of our solar system.

Large Matrix Interferometry

A new technique of planetary radar mapping, known as large matrix interferometry, was demonstrated in a radar experiment using Venus as a target. Because the radar beam is too broad to look at discrete parts of the planet, the new technique was necessary to resolve ambiguities. A brightness map covering an 8000 x 4000 mile area on Venus was obtained showing features observed only in crude form before, and an altitude profile was made of Mars to aid in the interpretation of Mariner 1969 data.

Pulsar Observations

Pulsars were observed using the Goldstone Venus station 85-foot antenna to determine their usability as a master time standard. One of the pulsars, PSR 0833-45, speeded up very suddenly during the week of February 24, 1969. The speed-up was probably caused by a change in the mass of the pulsar or in its internal structure. In either case, the fact that pulsars are highly relativistic has to be taken into account.

K-Band Amplifier Development

A theoretical and experimental study of the energy levels of ruby and chromium doped metals was conducted to determine the design parameters for a K-band maser, which operates at 10 times the frequency of the S-band masers used in the Deep Space Network. It was concluded that ruby offered the best figure of merit and simplicity of construction for a K-band maser. The techniques involved are much less sensitive to magnetic field orientation and, therefore, will be more phase- and gain-stable. A superconducting magnet will be used to produce the magnetic field necessary.

Deep Space Communications Techniques

Within the last year, a feasibility study was published on lasers and other exotic techniques for deep space communications. A study on optical techniques for precision deep space tracking was initiated. JPL has installed two “seeing” quality monitor systems at the joint Smithsonian Astrophysical Observatory-NASA Observatory on Mt. Hopkins in southern Arizona. Such monitoring is necessary to determine whether laser

Brightness map of Venus obtained using large matrix interferometry technique shows features observed only in crude form before.
signals can get through the earth's atmosphere without too much degradation.

A zone-plate antenna was conceived of as a possible method for utilizing a large balloon as a spacecraft antenna. The prototype demonstrated that the device works as anticipated. Missions to the outer planets will have to use low-noise command receivers aboard the spacecraft to provide command capability over the low-gain antenna throughout the mission. A receiver noise temperature of 300°K or less is required to achieve this capability. A new idea for a spacecraft command receiver was conceived, implemented entirely from digital circuits, that promises to satisfy the unprecedented performance and lifetime requirements of a Grand Tour mission. Breadboards and computer simulation have proven the basic concepts.

Zone-plate antenna.

**SPACECRAFT DEVELOPMENT**

The successful completion of flight experiments is largely dependent upon the unimpaired functioning of spacecraft hardware throughout all phases of a mission. The design and development of spacecraft involve not only the design and construction of individual components but also the development and use of adequate materials and the testing of the spacecraft and its components under simulated flight conditions.

**Thermoelectric Outer Planet Spacecraft Project**

The Thermoelectric Outer Planet Spacecraft (TOPS) Project was established in 1968. It is designed to take advantage of the unique opportunity occurring during the 1976–1980 period to launch spacecraft with long life, environment immunity, target missions to the outer planets, using booster vehicles of the Titan family. The purpose of the TOPS Project is to develop and demonstrate the technology required for the development of unmanned spacecraft with long life, environment immunity, and emergency adaptability characteristics.

The Project will include conceptual mission and system design, detailed design of selected subsystems, and fabrication and testing of other subsystems necessary to demonstrate particularly advanced component applications, subsystem performance, or system interfaces.

The Grand Tour missions were selected as the basis for study. This multiple flyby of the four major outer planets is an attractive reconnaissance mission, and similar launch opportunities will not recur for over 170 years.

During 1969, a first iteration of the functional requirements for the spacecraft design was made, and detailed design and breadboarding of the more advanced subsystems were in process. This effort indicated that the required technologies can be expected to mature adequately for the launch opportunities during the late 1970's.

**Attitude Control**

A conceptual design of an all-digital attitude control subsystem for the Thermoelectric Outer Planet Spacecraft was completed. The system offers significant advantages over its analog predecessor. It controls the spacecraft to a high degree of accuracy without attendant penalties in propellant use. It lends itself to the implementation of redundancy for long-life missions, and it readily interfaces with a spacecraft computer.

A digital sun sensor is currently under development to meet the requirements of the TOPS attitude control subsystem. A large fixed spacecraft antenna is to be continuously pointed toward earth by biasing the sensor's output in both pitch and yaw. The sensor accuracy must be maintained over the entire field of view of approximately 6 x 38 degrees. The sensor expresses the sun error angle in a grey, coded, digital work output.

A single-axis breadboard sensor, having 0.025-degree resolution over a 6-degree field of view, has been fabricated and is now under test.

**Electronic Packaging**

The design and development of the packaging and interconnects for the electronics of the Thermoelectric Outer Planet Spacecraft has progressed to the construction of a half-scale model of the electronics compartment. The compartment would contain plug-in assemblies of complete functional units such as radio or power. The use of microminiature connectors provides interconnection capability of 460 contacts per square inch. This is four times the interconnect density of Mariner-type spacecraft.

The assemblies can be built using a modular concept that has the flexibility of packaging large, bulky, conventional electronic parts or new types of components such as medium-scale integration (MSI), large-scale integration (LSI), or hybrid circuits.

It is estimated that over 1,000,000 equivalent electronic parts, compared to 110,000 for Mariner 1969, will be packaged in the compartment, whose volume is 90% that of Mariner.

The electronics compartment consists of a structurally integrated design, with each unit added to the compartment providing additional strength until the final assembled compartment has the greatest possible strength for its weight.

The heat generated in the compartment is conducted to a radiating surface oriented toward deep space. The room-temperature environment in the compartment, compared to the -350°F unregulated temperature outside the compartment, is maintained by insulating selected areas and controlling the finish on the radiating surfaces as well as using temperature-adjustable louvers to expose the radiating surface to space.

**Structural Composites**

New advanced structural composite materials such as boron/epoxy and graphite/epoxy exhibit good strength-to-density as well as high modulus-to-density ratios. These properties were reviewed for application in lightweight spacecraft structures, such as struts, rocket motor cases, and pressure vessels. The effort consisted of analysis, design, fabrication, and testing of prototype structures supported by material, and structural and analytical research.
with emphasis on boron and graphite epoxy systems. Boron/epoxy was selected on the basis of its larger use experience, more consistent material properties, better thermal properties, and compression strength. Design-allowable stress levels were established, and designs were developed for solid and liquid propulsion pressure vessels and spacecraft structural members using boron/epoxy as structural material.

A study was initiated to establish design values of boron/epoxy composite material processed under special conditions pertinent to lightweight pressure vessels and structures.

Space Environment Research

One area of considerable concern in space environment design/testing is the tendency of rubbing surfaces to experience increased friction in space. This process can proceed to the point of seizure or “cold-welding” and consequent failure.

During the year, an apparatus for exploring this phenomenon was obtained from the Air Force and tested in the 10-foot Molsink simulator. Sixteen separate channels were incorporated for friction investigation so that information on sixteen pairs of materials could be obtained simultaneously. Satellite data had been collected throughout a 1-year period. The device had also been carefully tested in a conventional vacuum chamber, and the correlation with the flight results was very poor. Results obtained in the Molsink test reproduced those obtained in flight. The facility has demonstrated, through this unique experiment, its ability to simulate the sensitive environmental parameters bearing on this process.

Temperature-Control Flux Monitor

The temperature-control flux monitor was flown aboard Mariner VI and VII to obtain a direct measurement of the solar constant, to aid in the establishment of a radiometric standard for future spacecraft testing, and to provide a comparison of spacecraft thermal test data with flight data.

Data returned by the instruments during the Mariner flights (February through September 1969) have resulted in what are believed to be highly accurate measurements of the solar constant, and have provided information on variations in solar thermal radiation. The results can be summarized as follows:

1. The value of the solar constant was measured at 135.25 mW/cm² ±1%.
2. Relative variations in the solar constant of tenths of one percent occur, the largest was 0.4%. As far as can be determined, these variations are random. No serious attempt has been made to correlate them with solar activity.
3. The variations occur over periods of hours to days; no short-term variations in terms of minutes were observed.

In regard to the engineering objectives of the experiment, the comparison between simulator test data and flight data showed good agreement, generally within 5°F. Therefore, it may be concluded that the environment provided by the present simulation facility is adequate for high-quality temperature/vacuum testing of spacecraft whose design employs the temperature-control concepts used in Mariner 1969.

Planetary Entry Research

The major source of heating for an entry vehicle during a braking maneuver in the atmospheres of earth, Jupiter, or Venus may be due to radiation. However, there is a factor-of-two uncertainty in the amount of radiative emission from the bow shock layer that would reach the surface of an entry vehicle. Two experiments were conducted to decrease this uncertainty.

To improve the fundamental knowledge of the radiating shock layer, measurements were made of the photoionization cross sections of the atomic gases nitrogen, oxygen, and carbon, which are the principal constituents in the shock layer in the cases of entry into the atmospheres of earth, Mars, and Venus. Results from vacuum ultraviolet spectrometer measurements agree well with theoretical calculations of the cross sections.

The measurements for atomic carbon were the first made for this system. Atomic carbon could be present in a Jupiter entry shock layer in the form of ablation products from the heat shield.

The other experiment was designed to observe the radiative self-absorption in the shock layer and the interaction between radiative and convective heating. A shock tube was used to drive a heated gas over a model in order to simulate the hot shock layer at the stagnation region of a planetary entry body. Model stagnation-point heating measurements obtained in air and in Venus atmospheric gas mixtures at simulated flight speeds from 7.5 to 12 kilometers per second agreed within 20% of theoretical calculations.

CHEMICAL PROPULSION

The basic application of chemical propulsion research is to the improvement of liquid and solid subsystems. Concomitant studies seek to improve propulsion equipment and to adapt the equipment to improved propellants. These efforts, in turn, require a constantly increasing understanding of the physical and chemical phenomena associated with rocket propulsion.

Planetary Orbiter Propulsion Engine

The initial evaluation of the 300-pound-thrust bipropellant rocket engine being developed for the Mariner Mars 1971 spacecraft was reported last year. Since that time, two complete prototype engines have been successfully demonstrated, with nine full-duration tests in excess of 800 seconds.
Prototype 300-pound-thrust bipropellant engine for Mariner Mars 1971.

Evaluation of the engine concept for more energetic missions such as the Viking orbiter is in progress, and continuous operation for durations of up to 3000 seconds has been achieved.

Propellant-Actuated Devices

For several planetary lander applications, there is a need to deploy items such as retarding parachutes and scientific samplers in a controlled manner. A solid-propellant-actuated device amenable to analytical design was developed and demonstrated for possible lander use.

The system utilizes hot solid propellant gases that are generated at high pressure in a small fixed volume and expanded in a controlled manner through nozzles into a low-pressure working chamber. The low-pressure gas then provides the working force to perform the required function such as ejecting a payload. The technique provides the high ballistic efficiency of a gun system and the design flexibility of a controlled low-pressure gas source. The concept was demonstrated using a prototype of an 11-inch-diameter parachute ejection device.

Nondestructive Test Technique for Electric Initiators

A major problem in qualifying electrically initiated squibs has been that the flight article could not be tested. Samples are normally drawn from a lot and tested to destruction. The qualification of the flight article is implied statistically.

Techniques for nondestructive sampling of such devices have been examined and instrumentation developed to allow determination of critical parameters and sample uniformity for the actual flight articles. A new technique utilizes the initiator as a resistive element of a wheatstone bridge excited by a sine wave and uses both the amplitude and phase of the bridge output as an indication of the sample element's heat loss and thermal capacity. The visual display allows a direct reading of the product of these two factors, the thermal time constant.

Various fabrication defects, such as poor bridgewire welds, can be determined from the optically displayed output. This method has proved so successful for the determination of sample uniformity in experimental development that it was incorporated into the qualification program of electrically initiated squibs to be used in the Mariner Mars 1971 flights. Anomalies detected using this new nondestructive test method were verified subsequently by destructive testing.

Low-Thrust Solid Propellant Rocketry

The concept of a case-bonded end-burning solid propellant motor is being considered to overcome the inherent limitations of that type of propulsion for low-acceleration attitude-stabilized spacecraft. By burning from the nozzle end forward, rather than radially outward as in the conventional contemporary applications, burning time is increased and the resultant spacecraft accelerations are reduced to levels acceptable to sensitive spacecraft components. In addition, the end-burning configuration provides a high mass-fraction efficiency, which in turn can produce the high-velocity increments demanded by future space missions.

Experimental work with the case-bonded end-burning solid motor has revealed that, as originally hypothesized, the propellants for such a motor must have unusually high elongation and a relatively low modulus of elasticity. The technical feasibility of the concept was demonstrated with the static test firing of 60-pound propellant charges in subscale flight-weight motors and, subsequently, in an 800-pound motor, approximately the size needed for a Jupiter orbiter mission. The test records revealed no signs of flaws or failures.

Binder Model Studies

Better rubbery mechanical properties in solid propellants may result from a better understanding of the kinetics and mechanisms of network polymer formation. Coordinated theoretical and experimental studies are being conducted toward this end.

Network polymers can be made to vary from soft rubbers to tough, hard solids according to the relative frequency of chain extension, chain branching, and chain termination. These processes were considered statistically; then models were tested experimentally by polyesterifications of compounds in compositions which are expected to reveal the incipient gelation boundaries of the systems. Study of the incipient gelation boundary has shown it to have the advantages of being theoretically predictable and physically identifiable.
Propellant samples being installed in arc-imaging furnace to test ignition characteristics.

Theoretical models were developed for several degrees of complexity, and good agreement between theory and experiment was obtained with a three-component model. However, two theories, which agreed in simpler systems, were found to diverge in their predictions for more complex systems. A definitive experiment will be made to show which theory is applicable to appropriate synthesized model compounds.

Heat Sterilization and Vacuum Effects on Solid Propellant Ignition Materials

The effects of heat sterilization and long-term storage in outer space on the ease of ignition of solid propellant igniter materials are not known. Any significant changes in ignition would influence the performance of the rocket motor.

Results of tests performed to measure the ignition characteristics of several materials showed a trend of increasing heating time required for ignition with increasing cycles of heat sterilization, i.e., a degradation in the ignitability of the materials. No effect of vacuum storage on ignitability was determined for any of the materials used.

SPACE POWER AND ELECTRIC PROPULSION

Advanced power systems for future spacecraft are needed for a wide variety of power ranges and mission profiles. In 1969, development was continued to satisfy these requirements in a variety of areas: nuclear power, solar power, and batteries. Electric propulsion becomes more attractive for application as missions become more demanding from the performance viewpoint. Significant progress was made toward making electric propulsion available for practical use.

Thermionic Reactor Power Sources

Thermionic nuclear reactor power sources convert heat from nuclear fission directly to electrical energy using power converters located within the reactor core. With NASA and the AEC, JPL is actively pursuing the design and technology development of such devices. Because of the complex coupling of nuclear, thermal, and thermionic characteristics in a reactor core, extensive computer analysis was undertaken to assess the inherent stability of this type of reactor. Results to date indicate that these devices are inherently stable provided a nuclear control system designed to achieve the desired response characteristics is used.

To study the stability and control characteristics, a pilot plant was constructed where several thermionic diodes could be operated in a typical thermal and electrical environment. Nuclear reactor characteristics were simulated by an on-line analog computer which controlled the rate of heat input to the diodes.

The system began operating early this year, and several phenomena, previously deduced analytically, have now been verified. The behavior of the system has been stable, and the experiment has resulted in some measure of confidence in our ability to predict the dynamic behavior of such systems.

Radioisotope Power Sources

Both experimental and analytical studies were initiated in an investigation of the radiation interference of radioisotope thermoelectric generator (RTG) power sources with spacecraft experiments or subsystems in a facility modified for the express use as an RTG radiation test laboratory. Isotopic fuels were characterized, and both neutron and gamma-ray spectra were calculated for several generator configurations being considered for flight programs. Initial estimates of interference levels and appropriate shielding requirements were based on existing data. The gamma-ray spectrum was measured for both SNAP-15A and SNAP-27 radioisotope power sources. The interference level of a selection of scientific instrument components was determined as a function of incident gamma-ray energy.

The development of isotope thermoelectric and isotope thermionic power sources was continued as part of a program for direct energy conversion. Several thermoelectric generators were evaluated for possible spacecraft power sources. Some of these units have been on life test for nearly 3 years. Work proceeded on the development of radioisotope thermionic generators with output power of 100 to 300 watts.

Liquid-Metal Magnetohydrodynamic Power Conversion

Investigations are continuing on the feasibility of a magnetohydrodynamic power-conversion system. The intent is to produce several hundred kilowatts of power. During
the past year, a power-conversion system has been operated with water and nitrogen to determine the system's hydraulic and electrical characteristics. Preparations for sodium-potassium (NaK)-nitrogen testing are in progress. An experiment to accelerate cesium-lithium mixtures at 1800 to 2000°F and measure the lithium velocity and the rate of erosion of a target surface is being prepared. A new method of separating the cesium vapor from liquid lithium downstream of the accelerating nozzle was simulated in water-nitrogen tests. A 5-megawatt dc motor-generator set for simulating the reactor heat source in future cesium-lithium conversion system tests was installed, and installation of a 5-megawatt NaK-to-air heat-rejection system is in progress. A study of the use of an MHD power system in a nuclear-electric spacecraft is being made by General Electric Company under JPL contract; a weight of 15,000 pounds including reactor and shield was estimated for an MHD power system of 240-kilowatt electric output.

Photovoltaic Power Sources
During the past year, significant gains were realized in the development of silicon solar cells doped with lithium which are resistant to the radiation environment of space. Previously, these cells suffered from low electrical conversion efficiency and instability. Experimental results indicate that the lithium-doped silicon cells can be as efficient as conventional solar cells and can exhibit a radiation resistance three to ten times that of the conventional cell.

Sterilizable Batteries
The second phase of the development of heat-sterilizable silver-zinc batteries resulted in the designing of engineering model cells which satisfy the large primary and limited-cycle electrical requirements. The large primary cell demonstrated acceptable performance after a wet life of more than a year and deep discharge cycling. Cells designed for a 25 ampere-hour capacity and ninety 50%-discharge cycles performed satisfactorily after being cycled more than 125 times, showing no effects attributable to sterilization. These cells are being evaluated for use in the Viking lander. The effort is now being concentrated on extending the cycle life and wet stand life capabilities of silver-zinc cells.

In the heat-sterilizable nickel-cadmium battery program, cylindrical 25-ampere-hour cells have been developed which show no degradation in electrical performance after more than 100 complete cycles. The energy density of these cells is equivalent to that of nonsterilizable cells.

Amalgam Electrode Cell
Studies of the reactions of zinc, cadmium, and silver electrodes have resulted in the discovery of the very-high-rate discharge-recharge capabilities of liquid amalgam electrodes. The power-producing capabilities of these electrodes are unique, as shown by the fact that in tests performed this year a potassium amalgam electrode was discharged at a current density of 8.1 amperes per square centimeter, with 80% charge recovery. This current density represents approximately a one-hundred-fold increase over the levels established for existing flight-model silver-zinc cells. The search is continuing for a suitable positive electrode possessing comparable characteristics that will permit the development of cells having many times the current drain capability of existing designs. Applications include high-current-drain devices such as landed vehicles or capsules with mechanical deployment capabilities.

Electric Propulsion Applications
A growing interest in an early application of electric propulsion technology has given impetus to the propulsion system technology demonstration program at JPL. During the year, a first-generation thrust subsystem, including two individually gimbaled thrusters mounted on a translating structure, a lightweight power conditioner connected through a switching network to one of the engines, and a failure detection network, was extensively tested. Life test data were generated on the translator and gimbal actuators, and many unsuspected interactions between the thruster and power conditioner were identified. A second-generation power conditioner incorporated the modifications required to overcome these interactions. This unit subsequently underwent a successful endurance test with an ion thruster, verifying that all problems encountered in tests on the previous model had been overcome. Assembly of a demonstration system for full closed-loop automatic operation is now beginning and will continue through 1970. Testing of the full system will start in 1971.

With the recent advances in electric propulsion hardware devices, the Laboratory has been placing more emphasis on the planning of electric propulsion missions and the development of flight-quality computer programs for mission support. These programs are now operational and are being used for analysis of Jupiter, Saturn, and Uranus orbiter missions in the early 1980's.

Recently, the software effort has been expanded to include both spacecraft guidance and orbit determination studies. Because propulsion is sustained over long periods of time, the guidance problems differ from those for ballistic missions or missions involving impulsive midcourse maneuvers for trajectory corrections. Orbit determination must take into account the high-level random accelerations acting on the spacecraft. Research was performed in stochastic modeling and sequential data filtering techniques, and analytic studies are under way in the area of engine reliability problems due to random failure.

First generation electric propulsion thrust system with two individually gimbaled thrusters.
PLANS AND PROGRAMS

The basic functions of planning and program formulation at the Laboratory include two principal aspects (1) the coordination of resource allocations (funds and manpower) to ensure consistency and compatibility with overall JPL and NASA plans and objectives, and (2) the examination and assessment of potential areas for the application of future Laboratory effort.

Resources Planning

Efforts continued to streamline the activities of budget preparation and manpower allocation through the development of standards, models, and improved methods of estimating. A step toward simplification is expected to emerge from a survey completed during the year defining the scope, purposes, and interrelationships of the various periodic institutional and programmatic planning exercises that are carried out throughout the Laboratory.

Budget and manpower plans are prepared and submitted to NASA twice yearly in response to specific guidelines. As an adjunct to these submissions, a new internal document was developed whose purpose is to maintain a consistent and up-to-date statement of the interests of the Laboratory and of the principles and goals expected to guide it during the next 5-year period.

Long-Range Planning Studies

Continuous attention is given to questions of long-range programmatic planning for the Laboratory. The planning involves not only prospective NASA assignments but also non-space activities, with a current target of approximately 10-15% of the total effort for the latter. It is anticipated that non-space work will be government-sponsored, and would provide some foundation for potential changes in the Laboratory mission in the event that revised national priorities indicate such changes to be desirable. JPL interest in non-space work is based on the recognition that such national social and economic problems as transportation, urban renewal, crime control, and environmental pollution may be amenable to attack by utilization of the technologies and management techniques developed in space-oriented endeavors.

During the past year, the principal efforts in non-space work were devoted to developing an effective program of support for the Department of Transportation. The task activity begun last year in support of the DOT Office of Research and Technology was continued.

Advanced Technical Studies

Lunar studies during 1969 were carried out cooperatively with the NASA Marshall Space Flight Center and the U.S. Geological Survey. Interest centered on the analysis of missions employing remotely controlled roving vehicles. Engineering work on navigation problems, ground-based operations,
and scientific instrument systems was undertaken. Mobile vehicles were tested under conditions simulating lunar soil on slopes. Advanced development work on remotely controlled imaging and sampling devices was begun.

In the field of planetary exploration, the major emphasis was directed toward proposed missions to the outer planets, in particular during the 1976–82 time period, when the five outer planets will have favorable positions relative to one another. As a result, the gravitational field of Jupiter can be employed to accelerate a spacecraft toward others of the outer planets, in this way greatly reducing the flight times and propulsion requirements otherwise required in direct flights to these planets. The primary candidate missions are to Jupiter–Saturn–Pluto for launch in 1977 and to Jupiter–Uranus–Neptune for launch in 1979. Advanced studies for these missions have proceeded beyond the mission analysis phase to consideration of specific systems designs.

Looking still further ahead, the requirements on orbiter spacecraft for both Jupiter and Saturn were studied to investigate their compatibility with the multiplanet fly-by systems. It was found that Jupiter and Saturn orbiters can readily be developed from flyby designs by the addition of a retrorropulsion system and some adaptations in the software systems.

Missions employing solar-electric propulsion techniques continued to be investigated, and during the year, two contracted studies were sponsored by JPL to examine the applicability of the concepts to asteroid belt survey missions in the mid-1970’s.

Another contracted study, initiated during the year and still in progress, deals with a prospective 1975 Venus multiprobe mission. The intent in this study is to define a mission and spacecraft capable of deploying several probes to penetrate the atmosphere of Venus at different locations around the planet.

**JPL NAVIGATION PROGRAM**

The coordination and enhancement of the research and development related to the Laboratory’s navigation activities, which are the function of the JPL Navigation Program...
Considerable focus was on community relations. For the first time in JPL history, doors opened to the public for a series of weekend open house observances co-hosted by technical and public affairs personnel.

Public Educational Services inaugurated a series of specialized science instruction seminars for teachers in the California Mentally Gifted Minors Program. Techniques for teaching basic concepts in spacecraft development and mission planning included practical laboratory application as the main theme of the series.

**UNIVERSITY RELATIONS**

Increased interest in the interaction of JPL with the university community was manifest throughout 1969. Besides the Resident Research Associate Program sponsored by NASA and the National Research Council, the Summer Faculty Fellowship Program sponsored by NASA and the American Society of Engineering Education, and the Summer Faculty Hiring Program, university research of interest to JPL was supported by the President's Fund and the Director's Discretionary Fund. In addition, the School of Public Administration, University of Southern California, initiated programs in management research at JPL. Approximately 25% of the California Institute of Technology faculty also had some involvement with the Laboratory during the year.

These activities, together with interaction with investigators in space experiments, participation of JPL staff as part-time faculty at local universities, and a widespread collaboration between individual JPL employees and their university counterparts, resulted in an interplay in which both JPL and the university community benefited.

**PRESIDENT'S FUND AND DIRECTOR'S DISCRETIONARY FUND**

During 1969, two programs supporting JPL-related research were instituted as a result of the Memorandum of Understanding. The President's Fund, used at the discretion of the President, California Institute of Technology, is funded in part by NASA and in part by the Institute. It is meant to provide support for research efforts of interest to JPL and to enhance JPL-university relationships. No more than half of the funding is awarded to investigators at Caltech, since the intent is to expand relationships within a broader university community. An additional aim is to introduce variety and new directions to JPL research.

The Director's Discretionary Fund supports work of interest to JPL and NASA at the discretion of the Director of JPL. The Fund may be used to provide seed money for new research areas, to enhance university relationships, and to make facilities available to the university community.

**CIVIL SYSTEMS PROJECT OFFICE**

In late 1969, a Civil Systems Project Office was established under the cognizance of the Assistant Laboratory Director for Research and Advanced Development. Both the Space Technology Applications Office and the Transportation Technology Office were placed under the responsibility of the Civil Systems Project Manager. The Space Technology Applications Office is chartered to investigate the application of techniques developed in the exploration of space to non-space problems of critical national interest in such areas as urban studies, medical engineering, and public safety support. The Transportation Technology Office has the responsibility of providing necessary research and technology support to the Department of Transportation, seeking to apply advances in space technology to critical transportation problems.

**PUBLIC AFFAIRS OFFICE**

To broaden the Laboratory's scope and increasing responsibilities in the public relations field, the Director placed under a newly created Public Affairs Office two existing sections, Public Information and Public Educational Services, and added two staff functions, Audio-Visual Communication and Internal Information.
FINANCIAL MANAGEMENT AND PROCUREMENT

A Memorandum of Understanding was entered into between Caltech and NASA in December 1968 and has had significant bearing on the operation of the Laboratory in its first year of application. The Memorandum served as a basis for a 3-year extension of the NASA/Caltech contract for the operation of the Laboratory and included programs for independent research and development to be utilized at the discretion of the JPL Director and the Caltech President. The programs promote independent research and development at JPL by faculty and students of Caltech and other educational institutions. NASA support for these programs amounts to $575,000 per year.

The automatic awards program, initiated by NASA in August of 1967, in the area of patents and new technology has resulted in 78 monetary awards to employees on 42 items published as Tech Briefs.

A contract in excess of $19,000,000 was placed with Collins Radio Company, Richardson, Texas, for the fabrication of two 210-foot antennas to be erected in Spain and Australia. It is expected that these new instruments will be operational by June 30, 1973.

JPL was requested to contract directly for the participation of NASA-selected scientific investigators in the Mariner Mars 1971 mission. Previously, such contracts were handled by NASA. Accordingly, in addition to the usual Memorandum of Agreement with the scientists involved, contracts were effected with nine educational institutions for the services of investigators and co-investigators.

The fabrication effort for the Mariner Mars 1971 Project was initiated with the execution of all contracts for the subsystems and related documentation.

A new supply catalog was issued and preparations are progressing to convert all JPL stock numbers to a Federal stock cataloging system. The Federal cataloging system allows for a “common language” for identification and description of materials which will promote greater standardization of supply items. The conversion will require the examination of some 50,000 line items which will be published in an integrated supply catalog in December 1970.

The FY '69 Cost Reduction Goal was $5,500,000. Of the 757 proposals submitted, 657 were validated for a total of $7,900,000, exceeding the goal by 44%. Included in the validated proposals was a savings of just under $2,000,000 accomplished by the reuse of surplus and salvageable items available in-house. Practically all organizations in the Laboratory either met or exceeded their cost reduction goal for 1969.
PERSONNEL

Partial relaxation in manpower constraints and the engineering and scientific labor market served to stimulate selective recruiting activities during the last half of the year.

 Approximately 185 students and faculty members were employed on a part-time basis in a plan designed to disseminate knowledge among professors, students, and others engaged in the space program's scientific and technological effort.

 Five persons were employed for training during the year under the Work Incentive (WIN) Program, a State and Federally sponsored and financed program for the underprivileged.

 The Summer Employment Program was continued: 235 were employed, including 45 young people hired under the auspices of the President's Youth Opportunity Program.

 The Employee Development Program was continued at a high level, with particular emphasis on management development. New courses included Effective Presentations, Management Information Systems, and Employee Appraisal. In addition to the technical development provided by tuition support and seminars, conferences, and short courses, JPL courses were offered in modern engineering, systems engineering, computer technology, and integrated circuits. The Resident Research Associates Program, co-sponsored by the National Research Council, increased to 24 participants. A Research Affiliate Program was started to encourage scientific and engineering faculty and students to make use of our facilities for mutual benefit. A Faculty Fellowship Program was conducted in conjunction with Caltech during the summer.

 Employees aged 30 and over with one year or more of service were given coverage under a revised noncontributory pension plan with improved vesting and a reduction in the normal retirement age from 68 to 65. Also, a voluntary, supplementary tax-deferred annuity plan was offered to be financed solely by employee contributions.

 Members of the Compensation and Records group participated in the formation of a San Gabriel Valley Compensation Association for the purpose of exchanging wage and salary information.
FACILITIES

The $2,000,000 standby power plant addition to the Space Flight Operations Facility (SFOF) was completed. This addition includes an uninterruptible power supply for the SFOF which eliminates effects on the computers of transient variations or momentary interruptions of power. In addition, it includes two 1380-kilowatt engine generators for use in the event of a power failure.

The first phase of the Protective Services complex was completed, providing new, expanded modern facilities for the Laboratory first aid station.

An addition to the Fabrication Shop was completed, providing 10,000 square feet of space for the weld shop and the sheet metal shop.

The high-temperature storage magazine was remodeled and additional space provided, converting the magazine to use as a toxic propellant laboratory for the Propulsion Division.

Surveyor Road, a main north-south artery, was improved between Mariner Road and Explorer Road. The work included widening and paving, curbs, gutters, sidewalks, and street lights. Work was started on the improvement of Explorer Road, including widening and repaving and the installation of new conduits for power and communications, together with a new 12-inch water line.

Increased emphasis by NASA on safety and fire protection resulted in JPL being funded to start the design of a building evacuation alarm and central reporting system, fire protection and safety items at Goldstone, and fire protection for the DSN stations.

Increased requirements for personnel housing resulted in the leasing of approximately 19,000 square feet in the Crest Professional Building in La Cañada.
SPECIAL RECOGNITION

The list of awards and appointments presented here is illustrative rather than complete. It is intended to indicate the involvement of JPL personnel in the government, academic, and professional communities and to reflect recognition of their accomplishments and contributions.

Honorary Awards
K. Aksnes, Dirk Brouwer Memorial Prize for unusual merit in astronomy, Yale University.
M. T. Chahine, NASA Exceptional Scientific Achievement Award for outstanding contributions in the field of remote sensing of planetary atmospheres and for discovery of a unique method by which the radiative transfer equation could be solved.
V. C. Clarke, Jr., and M. S. Johnson, NASA Exceptional Service Award for exceptionally qualified and dedicated efforts toward mission objectives and operations planning in the Mariner Mars 1969 Project.
P. M. Muller and W. L. Sjogren, NASA Exceptional Scientific Achievement Award for the discovery of lunar mascons.
W. H. Pickering, Gold Cup Man of Achievement Award, Achievement Rewards for College Scientists.
N. A. Renzetti, NASA Exceptional Service Award for outstanding and sustained technical leadership as Tracking and Data System Manager for the Ranger, Mariner, and Surveyor Projects.
H. M. Schurmeier, NASA Exceptional Service Award for outstanding contributions in successfully attaining the objectives of the Mariner Mars 1969 program.
Mariner Mars 1969 Project Team, NASA Group Achievement Award for successfully attaining the objectives of the Mariner Mars 1969 program.

Appointments
A. A. Avizienis, Participant, Distinguished Visitors' National Lecture Series, Institute of Electrical and Electronics Engineers.
M. F. Easterling, Visiting Professor, Applied Science, California Institute of Technology.
R. M. Goldstein, Visiting Associate Professor, Radar Astronomy, California Institute of Technology.
N. H. Horowitz, Member, National Academy of Science.
J. N. James, Fellow, Institute of Electrical and Electronics Engineers.
S. H. Kalfayan, Fellow, American Institute of Chemists.
C. L. Lawson, NATO Fellowship in Mathematics Applications, Atomic Energy Establishment, United Kingdom.
C. S. Wu, Research Professor, Institute of Applied Mathematics and Fluid Dynamics, University of Maryland.
Jet Propulsion Laboratory Executive Council

W. H. PICKERING, Director
J. E. CLARK, RADM—USN (Ret.), Deputy Director

W. H. BAYLEY  Assistant Laboratory Director—Tracking and Data Acquisition
J. P. CLICK  Assistant Laboratory Director—Financial Management and Procurement
C. W. CRAVEN  Executive Assistant to the Director, Secretary to the Council
F. H. FELBERG  Assistant Laboratory Director—Plans and Programs
F. E. GODDARD  Assistant Laboratory Director—Research and Advanced Development
J. N. JAMES  Assistant Laboratory Director—Technical Divisions
W. H. PADGHAM  Assistant Laboratory Director—Personnel Administration and Supporting Services
R. J. PARKS  Assistant Laboratory Director—Flight Projects
H. J. STEWART  Advanced Studies Advisor
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