Jet Propulsion Laboratory

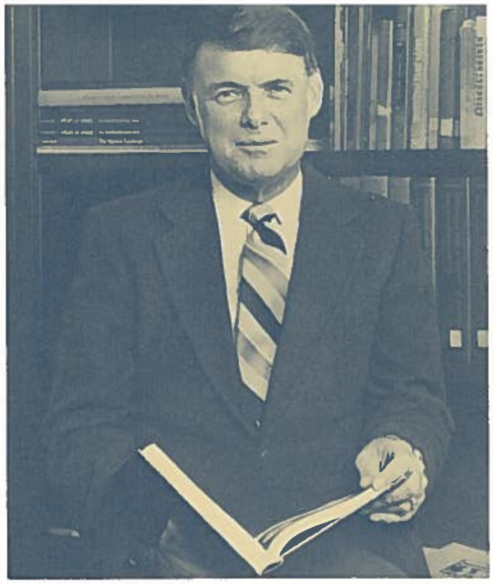
1980 Annual Report

Cover: This photograph of Titan's upper atmosphere was taken by Voyager 1 on November 12, 1980, at a distance of 22,000 kilometers from the satellite.

Contents

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 to December 31, 1980.

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California



Director's Message

For one week in November, the world turned a collective eye on the Jet Propulsion Laboratory as Voyager 1 made its dramatic excursion through the Saturnian system. People everywhere responded to the adventure and to the splendor of the discoveries and admired the United States' technological excellence. Not since Apollo a decade ago have U.S. citizens and the people of the world been more captivated by a space expedition. Voyager truly is an example of how America's deep space exploration program can properly earn the world's respect and admiration, as well as symbolize to our own people their aspirations for our nation's future.

While making news and history simultaneously, Voyager 1 drastically improved our understanding of the Saturnian system — thanks to a near-perfect operation carried out by the mission flight team, support personnel, and the Deep Space Network. The scientific bonanza will be multiplied when Voyager 2 flies by Saturn next August.

As the nation's lead center for deep space exploration, JPL also pushed ahead with preparations for two major flight projects — Galileo and the International Solar Polar Mission.

The Galileo mission to Jupiter will send a spacecraft into orbit around the giant planet, beginning a prolonged examination of its weather systems, its turbulent magnetosphere, and its diverse collection of moons, and send an instrumented probe into the Jovian atmosphere.

Galileo is now planned for launch in 1985, after schedule slips and configuration changes due to the launch vehicle development delays.

The International Solar Polar Mission, intended to make unique observations of solar phenomena from above and below the plane of the solar system, was to have employed two spacecraft, one European and one American. They would be launched to Jupiter, where that planet's huge gravity would fling them into trajectories passing over the poles of the Sun. This mission also experienced delays and revisions due to the launch vehicle situation, but now it is threatened more seriously. NASA, within the various budget constraints provided by the Office of Management and Budget, has found it necessary to recommend that the U.S. spacecraft be terminated and only the European spacecraft launched by the Shuttle-Centaur in 1986. The outcome is still uncertain as of this writing.

The Venus Orbiting Imaging Radar mission is now rescheduled for launch in 1988. The spacecraft will carry a mapping radar and a high-capacity data system into Venus orbit to obtain images of the permanently cloud-shrouded Venusian surface. The high-resolution global radar coverage will open up the planet and its geological processes to our eyes as did Mariner 9 and the Viking Orbiters at Mars.

The Halley's Comet Intercept mission remains under study and the U.S. may yet be able to join the several nations who have indicated interest in rendezvousing with the comet in 1986. Halley's Comet comes close to Earth only once every 76 years.

Two Earth satellite projects managed by the Laboratory will return data from polar orbit in 1982 and 1983. The Infrared Astronomical Satellite, an international effort involving the United States, the Netherlands, and Great Britain, will conduct a year-long infrared telescopic survey of the sky. The Solar Mesosphere Explorer will determine the effects of solar radiation on the Earth's ozone layer.

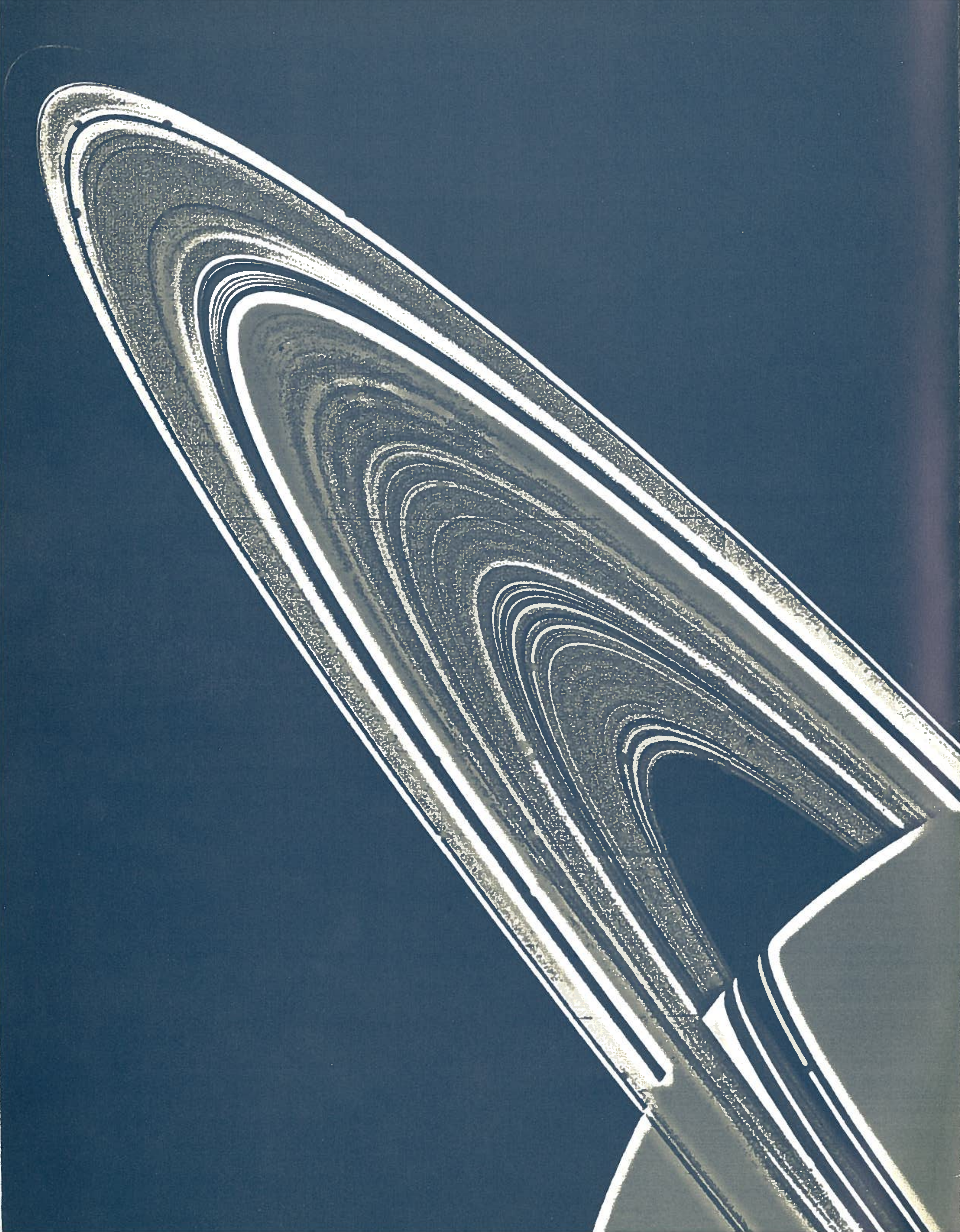
In its 36th year as a government-sponsored organization, the Laboratory continued to expand its developmental contributions to alternative energy sources. These endeavors were mostly concerned with photovoltaic and solar thermal forms of solar energy production. Other JPL research tasks and technology studies contributed energy-saving ideas and techniques.

Our high-caliber professional staff continued to meet mounting challenges with great competence and skill. We have a tradition of excellence and ingenuity at JPL that is widely known, and that gives the people who work here a strong sense of pride, identity, and purpose.

In spite of uncertainties, JPL and its leadership look forward to a decade of steady contributions to the United States' space exploration program and the nation's overall energy development.

Bruce Murray

BRUCE MURRAY
Director



Deep Space Exploration

The historic flyby of Saturn by Voyager 1 and the scientific discoveries concerning the planet's many rings and moons were the high points of the 1980 deep space program at JPL. Mission operations plans now center on the Voyager 2 follow-up visit to Saturn in August 1981.

As the lead center for NASA's planetary programs, the Laboratory also continued development of two future missions — Galileo, a projected return to Jupiter and its major moons, and the International Solar Polar Mission, a joint effort by NASA and the European Space Agency to study the Sun.

Planning proceeded for possible Venus and Halley's Comet missions and for other planetary science experiments to be carried out from space and Earth.

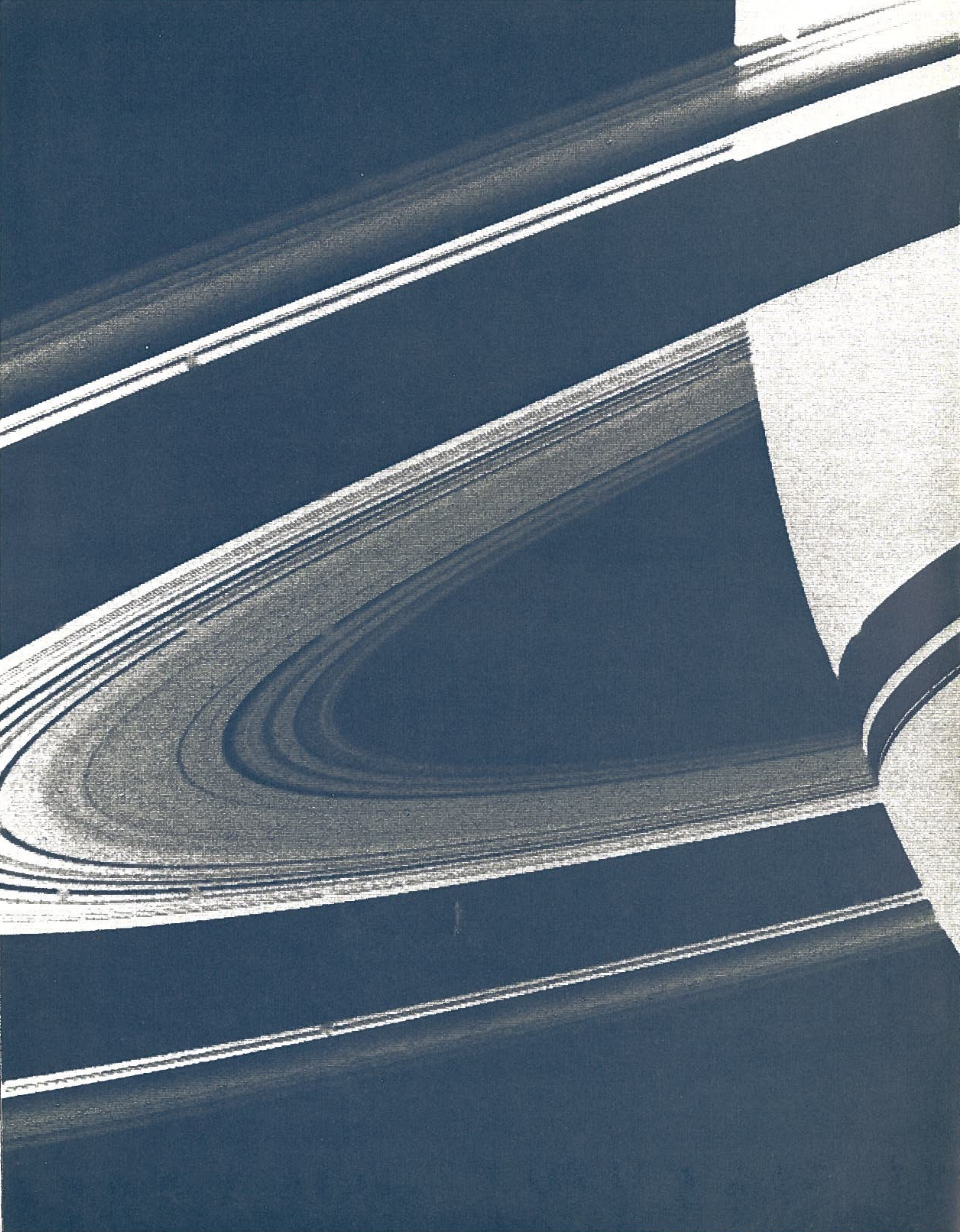
Tracking and data acquisition by the Deep Space Network (DSN), which JPL operates for NASA, continued at a high level of efficiency. Besides supporting Voyager at Saturn and Viking at Mars, the DSN monitored Pioneer 10 to a record 3.4 billion kilometers from Earth and tracked Pioneer 6, which, at 15 years, is the oldest spacecraft returning scientific data.

This computer-assembled two-image mosaic of Saturn's rings, taken by Voyager 1 on November 6, 1980, at a range of 8 million kilometers, shows approximately 95 individual concentric features in the rings. The narrow F ring is less than 150 kilometers wide.

Voyager

The Voyager Project continued its planned exploration of the outer planets through Voyager 1's detailed investigation of the Saturn system. The Voyager 1 spacecraft and its support equipment performed flawlessly and provided a wealth of new information about Saturn's atmosphere, satellites, magnetosphere, and rings. A high level of press coverage at JPL, along with live television programs, which were distributed widely throughout the United States, Mexico, Europe, Japan, and Australia, enabled millions of people to share the excitement of discovery.

The two Voyager spacecraft were launched in the summer of 1977. Voyager 1 had its closest approach to Jupiter on March 5, 1979, and Voyager 2 on July 9, 1979. After its 18-month cruise from Jupiter to Saturn, Voyager 1 observed the Saturn system for 117 days, from August 22 through December 16, 1980, with closest approach to Saturn on November 12. Some 17,000 images, along



with a steady stream of data from Voyager's other instruments, were acquired through the integrated efforts of the Deep Space Network, the Mission Control and Computing Center, and the Voyager Flight Team.

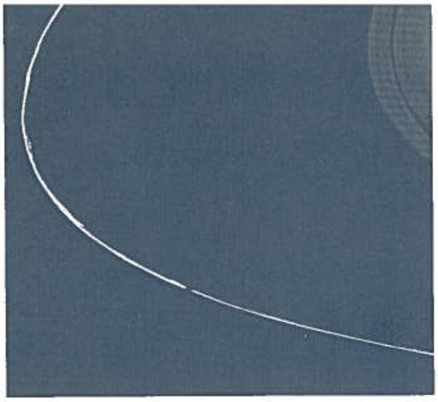
Voyager 1 departed Saturn on a flight path that is taking it up and out of the plane of the ecliptic (the plane in which the Earth orbits the Sun) in the general direction of the solar apex (the point on the celestial sphere toward which the Sun is traveling) at a rate of 3.4 astronomical units (508 million kilometers) per year. It will investigate this unexplored region, taking fields and particles measurements, and eventually explore the edge of our solar system and the interstellar medium beyond. Voyager 2, flying a slower trajectory, will begin its observations of Saturn in June 1981, with closest approach next August 26.

Voyager 1 science experiments produced new findings concerning the Saturnian magnetosphere, the atmosphere, the rings, the icy satellites, and the largest moon, Titan.

Saturn's magnetosphere extends about a million miles in the sunward direction. Normally, Titan's orbit lies entirely within the magnetosphere, but in periods following high solar activity, the magnetopause may temporarily lie within the orbit of Titan on the sunward side of Saturn. Corotating plasma normally sweeps by Titan at speeds of more than 32 kilometers per second, creating a cosmic generator that gives rise to a 6000-volt potential across Titan. Because Titan possesses no intrinsic magnetic field, and therefore does not now possess a liquid metallic core, its atmosphere and surface are continually bombarded by the plasma ions. A large torus of neutral hydrogen envelops the orbits of Titan and Rhea, presumably with Titan as the source of the hydrogen.

Charged particles spiraling into Saturn's polar regions produce auroral activity in a manner similar to that at Jupiter. Aurora-like emissions are also seen nearer Saturn's equator at the illuminated limb. Evidence of periodic electrical discharges within the rings of Saturn was found.

Alternating belts and zones in Saturn's atmosphere extend to higher latitudes than on Jupiter, possibly an indication that Saturn has a smaller liquid hydrogen core. Rotational features are present, but are muted by the much thicker haze layer above Saturn's clouds.



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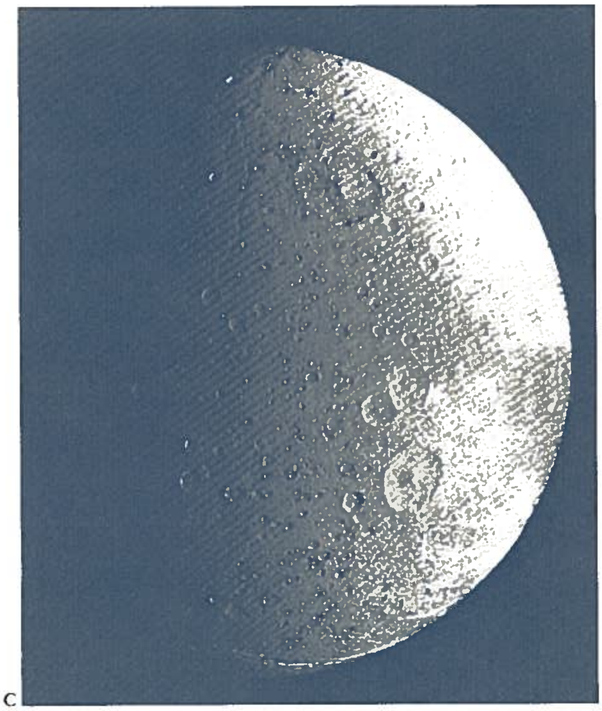

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A. The rings and limb of Saturn are seen from the southern, unilluminated side of the rings; this image was taken by Voyager 1 on November 12, 1980, at a range of 700,000 kilometers.

B. Saturn's outermost ring, the F ring, was photographed at a range of 750,000 kilometers.

C. Saturn's moon Dione shows many impact craters, the result of collisions with cosmic debris. The largest crater is less than 100 kilometers in diameter.

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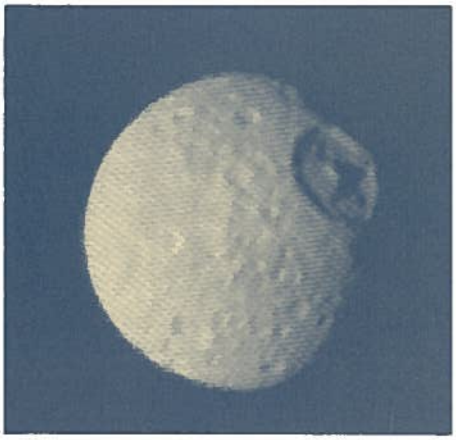
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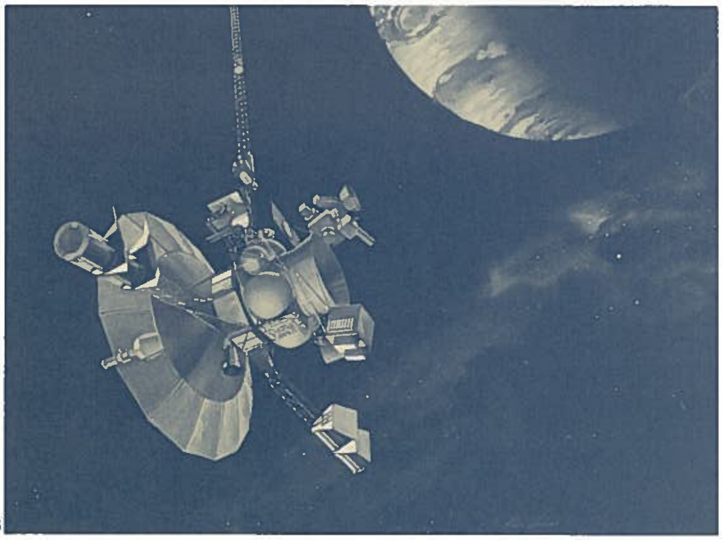
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Periodic 175-kilohertz radio signals define a body rotation period of 10 hours, 39 minutes, and 26 seconds for Saturn. Cloud velocities reach almost 1770 kilometers per hour near Saturn's equator.

The visible rings of Saturn are subdivided into hundreds of ringlets of varying brightness. Voyager verified the existence of a previously unseen D-ring between the C-ring and the cloud tops. The Cassini Division is seen to consist of more than a dozen ringlets. The tiny F-ring has at least three ringlets shaped to make the F-ring appear braided. Dust-sized particles in the B-ring form finger-like spokes that extend over thousands of miles of radial distance. Mean particle sizes in the C-ring, Cassini Division, and the A-ring are 2 meters, 7 meters, and 8 meters, respectively. B-ring mean particle diameters are probably even larger. A wide distribution of sizes around the mean is expected for each of the rings.

With the discovery of three new moons near the outer edge of the rings, the number of known Saturnian moons reached 15. All except Titan and Enceladus appear heavily cratered. Their densities are near that of water, and their surfaces highly reflective. The newly discovered moons have irregular shapes while Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, and Iapetus are very nearly spherical.

Enceladus lacks any visible craters at a resolution of 6.5 kilometers, and is the most reflective of the moons. It is possible that tidal forces due to its orbital resonance with Dione may have heated the surface and subsurface, thereby destroying evidence of past bombardment.

Titan's 320-kilometer-thick haze obscures the surface at all wavelengths from the ultraviolet through the infrared. Nitrogen is the main component of the atmosphere; methane, ethane, acetylene, and hydrogen cyanide are lesser constituents. At the surface, atmospheric pressure is 60 percent higher than the sea-level atmospheric pressure of Earth. At Titan's temperature of 90 kelvins, methane may exist in solid, liquid, and gaseous states and play a role on Titan similar to that of water on Earth. The diameter of Titan, second only to Jupiter's Ganymede among moons, is about 5136 kilometers.

The Voyager mission to date has provided an excellent data base for satisfying primary mission objectives through comparative studies of the Jovian and Saturnian systems and interplanetary space from Earth to Saturn. Because Voyager 1 attained its objectives so well at Titan, Saturn, and Saturn's rings, NASA has approved a Project recommendation to change the trajectory of Voyager 2 to a Saturn flyby that will carry the spacecraft to Uranus in 1986 and possibly Neptune in 1989.

Galileo

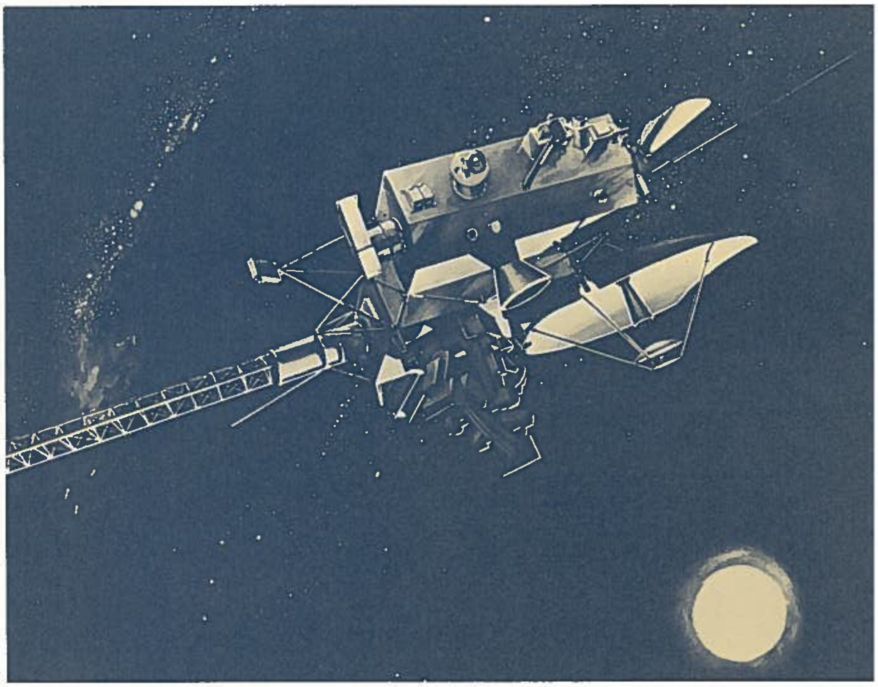
This scientific successor to the Voyager missions to Jupiter will employ an Orbiter and a Probe to explore the giant planet and its four largest moons, which were discovered by Galileo in 1610. The Orbiter is scheduled to orbit Jupiter for 20 months and investigate the moons Callisto, Europa, Ganymede, and Io, while completing at least 11 orbits. The Probe will penetrate the Jovian atmosphere after release from a Carrier spacecraft. The science investigation will include eleven experiments on the Orbiter and seven on the Probe. Principal objectives are to study Jupiter's weather systems and to determine atmospheric constituents.

The 1979 decision to slip the 1982 scheduled launch to 1984 forced several changes in the mission and spacecraft designs. The dominant effects were to increase the launch energy needed and require separate launches for the Orbiter and Probe, in February and March of 1984, respectively, on Space Shuttle/Inertial Upper Stage (IUS) launch vehicles. System redesign was accomplished and a mission and system review was held for the revised mission.

Toward the end of 1980, IUS development problems decreased the probability of a launch in 1984, and, in December, a recommendation was made to delay the launch until March 1985 and return to a single Orbiter/Probe on the Shuttle using a Centaur upper stage.

International Solar Polar Mission

Developmental work proceeded on two spacecraft and eleven instruments for international scientific investigations of the Sun and its interaction with space from a perspective above and below the plane of the ecliptic. For this mission, NASA was to have furnished



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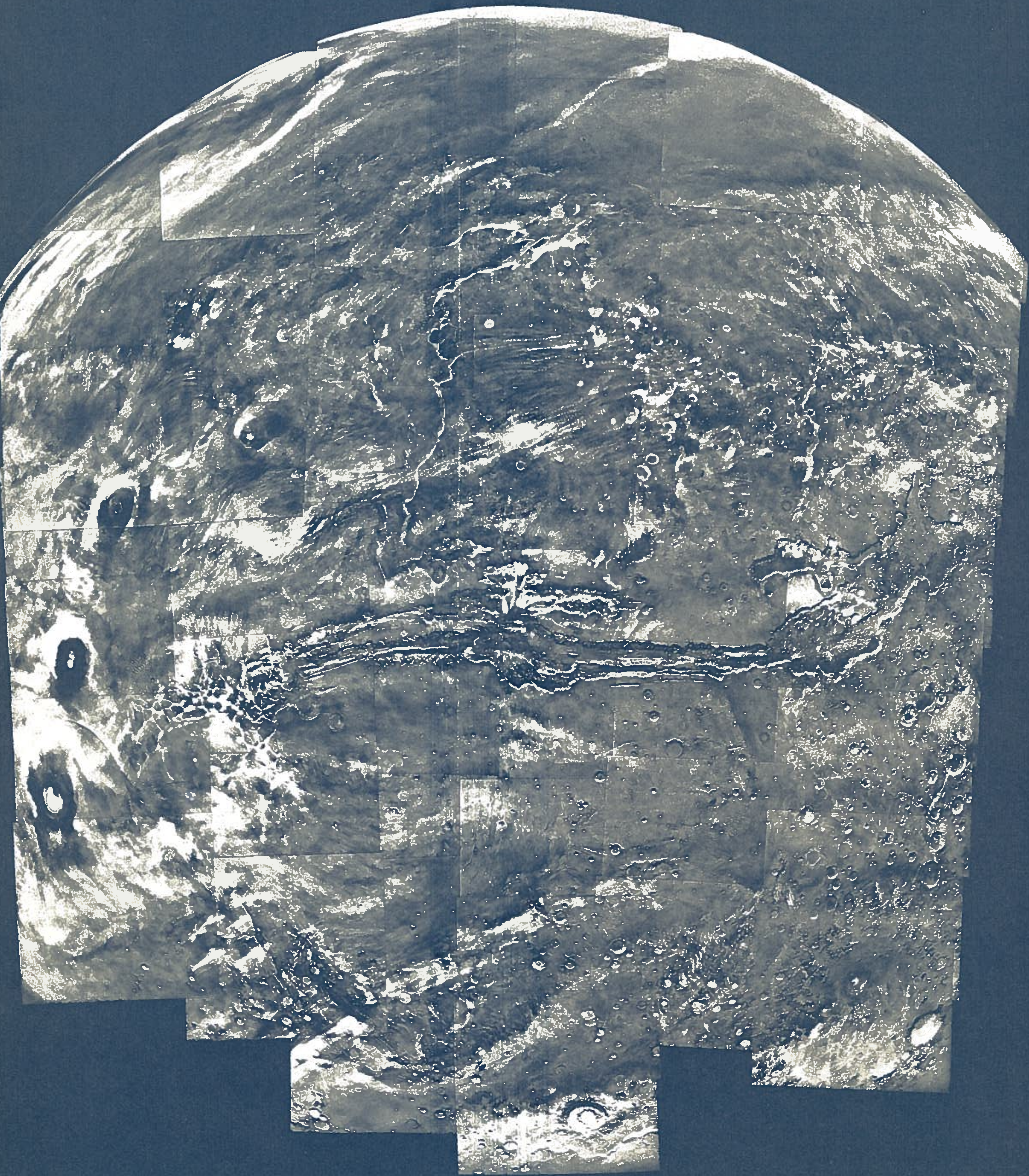
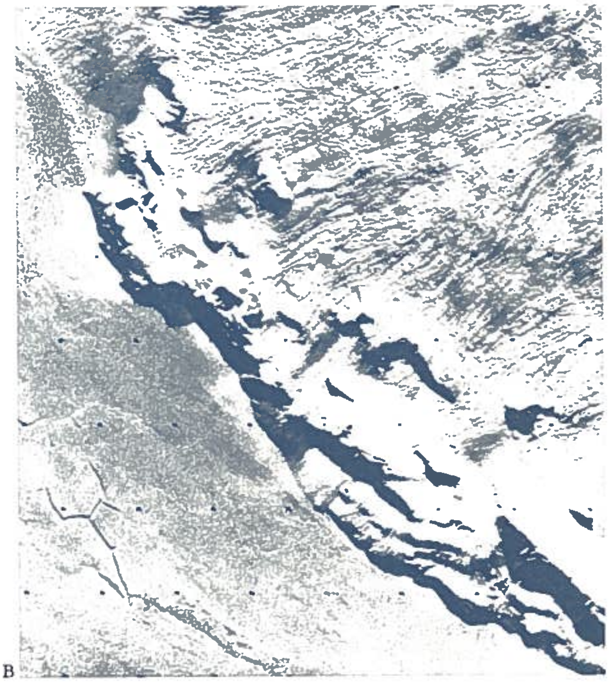
A. Saturn's moon Mimas was photographed by Voyager 1 on November 12, 1980, from a range of 425,000 kilometers. The numerous smaller craters indicate an ancient age for Mimas' surface.

B. As the Project Galileo Orbiter circles Jupiter, the spacecraft will photograph the planet's cloud tops and the Galilean satellites.

C. The International Solar Polar Mission to the Sun would explore the unknown polar areas of our star.





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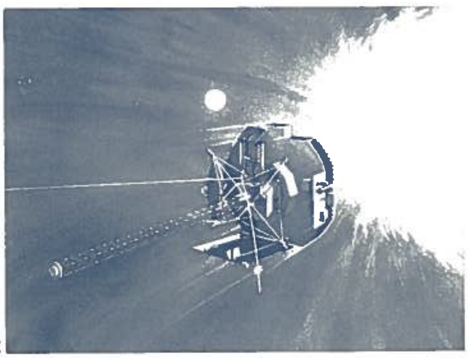

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A. One hundred and two photographs taken on February 22, 1980, by Viking Orbiter 1 compose this mosaic of Mars.

B. This photograph of the scarp or cliff that surrounds Olympus Mons, a Martian volcano, was taken by Viking Orbiter 2 from an altitude of 4,000 kilometers.

C. As the spacecraft approaches Halley's Comet, the shield shifts its orientation from the Sun (left of the spacecraft) to the dust that surrounds the comet's nucleus.

one spacecraft, to be built by TRW; another would be supplied by the European Space Agency (ESA). It is being built by Dornier Systems in the Federal Republic of Germany. JPL is responsible for the development of six instruments on the ESA spacecraft and five on the NASA spacecraft.

Launch vehicle problems in 1979 forced rescheduling of the launch from 1983 to 1985. The postponement resulted in a plan for separate launches with the Shuttle IUS for the NASA and ESA spacecraft. Work in 1980 was directed toward replanning and trimming costs. Design work on the instruments and several critical spacecraft subsystems continued almost on the original schedule.

For either launch plan, the trajectories flown by the spacecraft would be comparable. Each spacecraft will pass Jupiter at roughly 30 degrees north or south and will use Jupiter's gravity to rotate the spacecraft and direct them back toward the Sun's poles. The mission duration for both a north and south polar passage will be roughly 4½ years.

However, early in 1981 NASA recommended elimination of the NASA spacecraft, launching of only the ESA spacecraft on a Shuttle Centaur, and further delay of the single spacecraft launch until 1986.

Viking

The Lander 1 location on Mars was designated by NASA as the Tim Mutch Memorial Station, in honor of the late scientist who contributed immeasurably to the Viking mission and the expansion of knowledge of Mars.

Viking Orbiter 1 operations continued until August 7, 1980, when it was commanded to shut off its transmitter, having exhausted its supply of attitude control system gas. Between November 1979 and the end of the Orbiter mission, over 7,000 moderate-resolution pictures were taken, including some stereo and color images of Olympus Mons and the Tharsis range. About 50,000 Orbiter images were received during the mission.

Lander 1, preprogrammed to provide weekly data segments to Earth, continues to provide engineering, meteorology, imagery, and radiometric data. Images acquired will be repeated at least once every Martian year to record observable changes on the surface. Meteorology data processing continued to monitor recurrences of previous weather pat-

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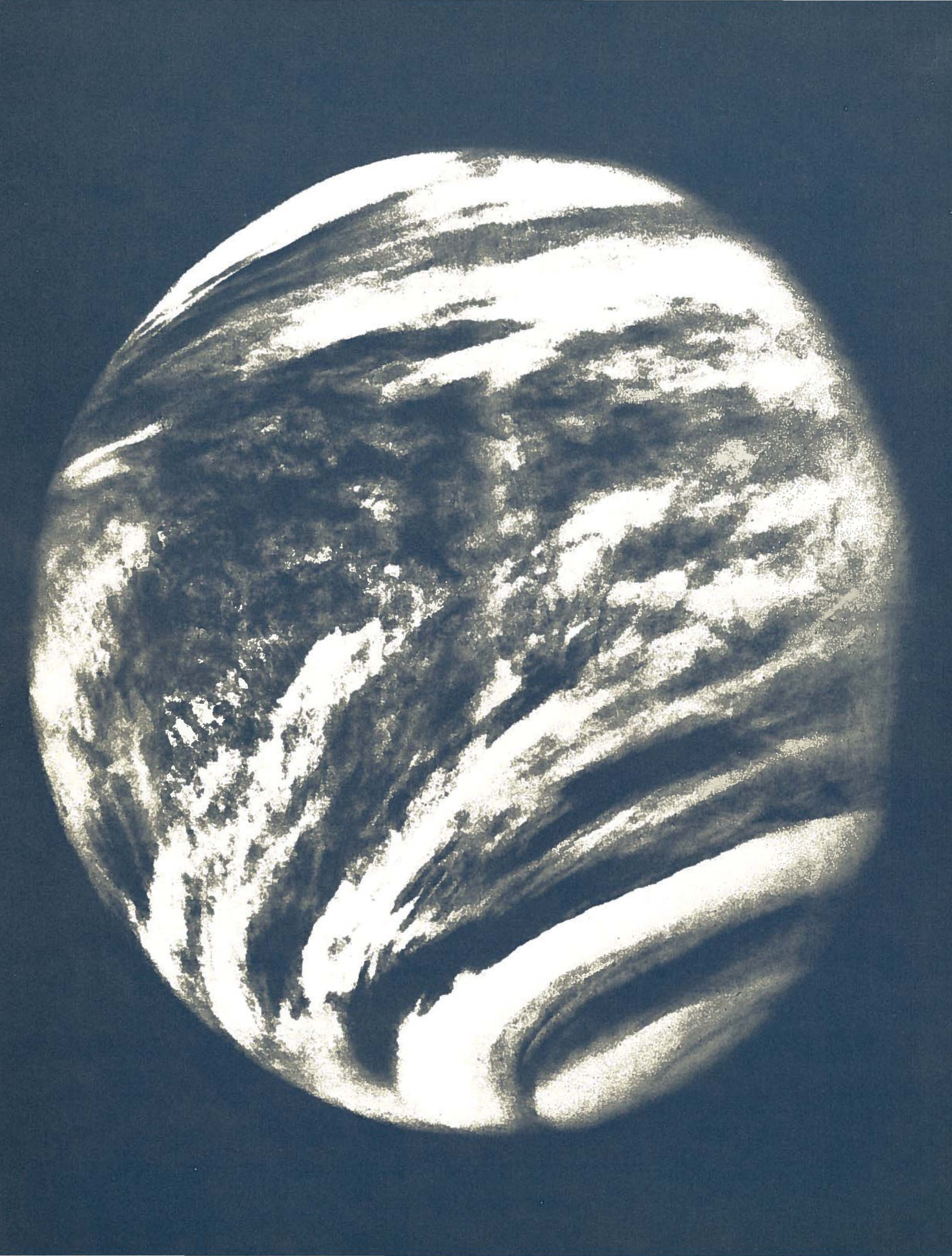

terns and dust storms. Radio scientists continued range and doppler measurements for planetary ephemeris and general relativity studies. The Lander preprogramming was extended nearly five years to December 1994.

Just prior to planned shutdown, Lander 2, which relied on Orbiter 1 for relaying its data to Earth, automatically terminated operations in April, when it sensed a low voltage on the power system bus.

Venus Orbiting Imaging Radar

The Venus Orbiting Imaging Radar mission is intended to map at least 70 percent of the planet's surface using synthetic aperture radar to pierce the thick cloud cover. The radar images and gravity data from tracking will provide an understanding of the processes that have shaped the surface of the Earth's twin planet. Other instruments will study the atmosphere.

Phase B studies for the spacecraft and radar were performed by contractors, leading toward an anticipated 1982 start and 1986 launch. Subsequently, the launch has been deferred 19 months to 1988.

Halley Intercept Mission

This mission, under study for a possible 1982 start, would send a Voyager-type spacecraft to a close flyby (within 965 kilometers) of Halley's Comet early in 1986. A high-speed imaging system and full complement of scientific instruments would provide information about the chemical and physical nature of the comet's nucleus, coma, and tail, and interaction between the comet and the solar wind.

The intercept would take advantage of Halley's first appearance near Earth in 76 years. Because the spacecraft and comet will approach each other at a relative speed of 208,000 kilometers per hour, the craft would be heavily shielded to protect cameras and other instruments from dust particles around the nucleus.

Extreme Ultraviolet Explorer

Extreme ultraviolet radiation, emitted by very hot stars and other objects radiating in the

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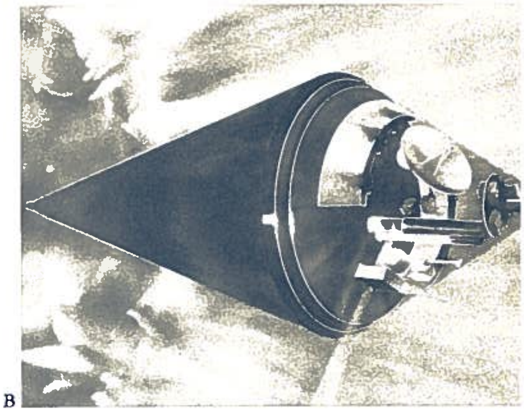

A. The near-global coverage of the Venus Orbiting Imaging Radar will penetrate the thick clouds of the Venusian atmosphere to produce high-resolution images of the surface.

B. The Starprobe would travel to within a few solar radii of the Sun's surface to obtain direct measurements of surface phenomena and the corona, and indirect measurements of the interior.

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region between x-rays and visible light, can be observed only by sensors above the Earth's atmosphere. In 1980, NASA assigned to JPL the task of preparing a satellite (the Extreme Ultraviolet Explorer) for an orbital all-sky survey in this spectral region, using telescopes and detectors that have been under development for several years at the University of California, Berkeley.

Starprobe

This mission, formerly called Solar Probe, continues to be the subject of preparatory studies aimed toward a NASA flight project in the mid-80s. At JPL, work began on the problems of communicating through the solar coronal plasma and of keeping the spacecraft on an undisturbed course, so that precision tracking could reveal the true shape of the Sun's gravitational field, thus giving information about the deep interior of our star.

At the Ames Research Center, work was started on concepts for shielding the Starprobe spacecraft from heating during the close flyby when solar radiation will be 3000 times more intense than sunlight at Earth.

Planetology Program

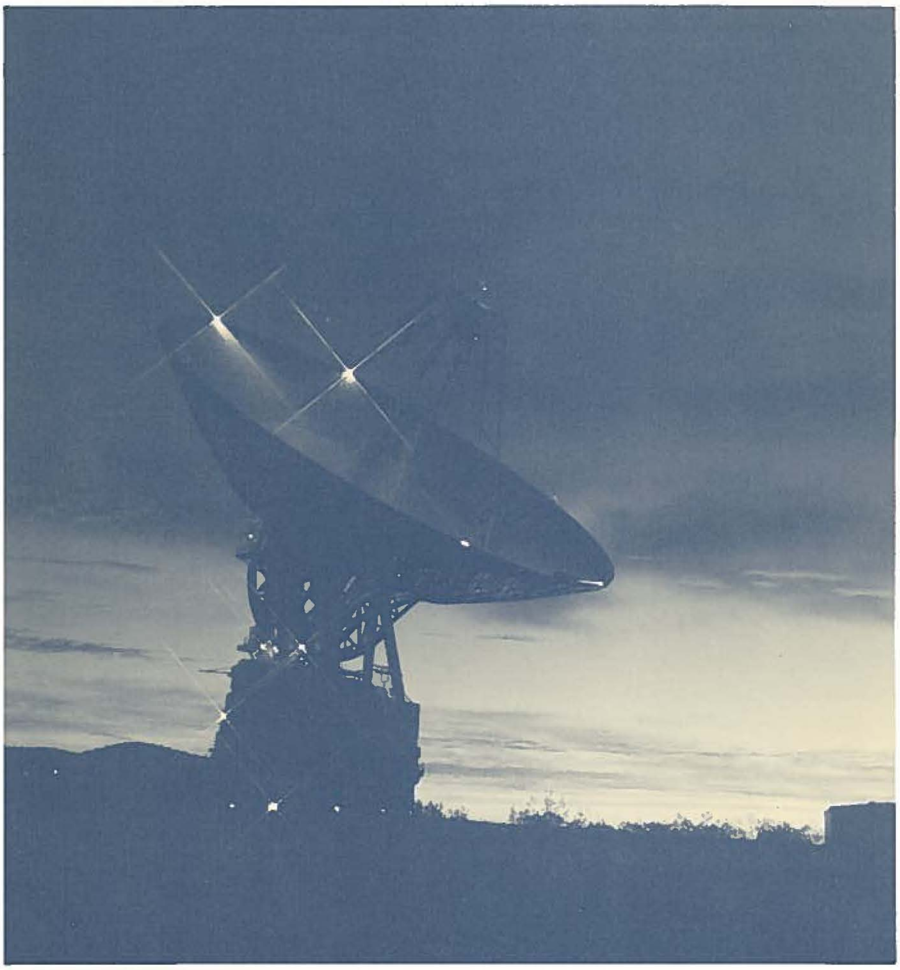
The Viking Lander Monitor Mission, as described above, will continue as part of the JPL planetology program through 1994.

The asteroid Anteros, a candidate for an exploration mission, was shown, by telescopic observations at visual and infrared wavelengths, to have a silicated surface. A radiometric model of this Earth-crossing asteroid indicated that its diameter is less than 2.5 kilometers and its visual geometric albedo is 0.13 ±0.03.

Voyager observations of hot spots on the Jupiter moon Io led to reexamination of Earth-based infrared observations. These helped to determine that the average heat flow through Io's surface would compare to an active geothermal area on Earth such as Yellowstone. The data imply that Io has a partially molten interior.

Telecommunications and Data Acquisition

The JPL Office of Telecommunications and Data Acquisition manages the planning,



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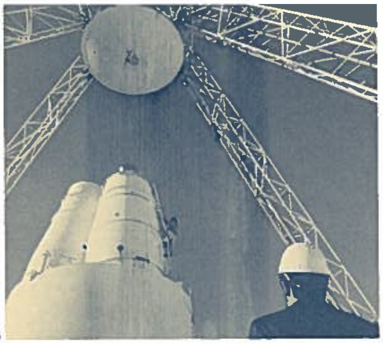
A. The 64-meter antenna at Goldstone, California.

B. Maintenance atop the receiving cone on the 64-meter antenna at Goldstone, California.

C. The Space Flight Operations Facility is the center for mission operations, where spacecraft tracking and scientific data are received from NASA's Deep Space Network and processed.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development, and operation of the Deep Space Network for the NASA Office of Space Tracking and Data Systems. The DSN's primary role is to provide worldwide tracking and two-way communication with spacecraft exploring the solar system, and, in the future, with highly elliptical Earth orbiters not tracked by the Tracking Data Relay Satellite. The basic elements of the DSN are three deep space communications complexes located at Goldstone, California; Madrid, Spain; and Canberra, Australia; a ground communications facility; and a Network control center at JPL.

Operations

The major DSN operational support provided in 1980 was for the Voyager 1 encounter of Saturn. The DSN provided command, telemetry, and tracking coverage for the entire 117-day period.

Three improvements at all three stations enabled an increase in the data telemetry rate from Saturn from 29.9 to 44.8 kilobits per second. This 50-percent increase in Voyager imaging information was the combined result of new maser designs reducing noise levels, better antenna feed horns, and joint arraying of 64-meter and 34-meter antennas.

The DSN obtained over 17,000 high-quality digital images of Saturn, its rings, and its satellites from a distance of approximately 1 billion kilometers. Overall, 99.7 percent of the planned images were provided, with only a small number degraded because of heavy rains in Spain and Australia.

Extremely challenging radio science experiments provided data from the Titan occultation, Saturn occultation, ring occultation, and ring scattering. The Saturn ring occultation experiment was the most technologically advanced radio science experiment conducted to date.

The DSN supported several radio astronomy activities, including implementation of the Tidbinbilla short-baseline interferometer, the most sensitive instrument of its kind in the southern hemisphere. Early observations yielded a very high detection rate of S-band radio sources. Other activities included monitoring the Velva pulsar (PSR 0833) in anticipation of a possible "star quake," a resurgence in the Jupiter patrol, and continuing observations of the energetic galactic


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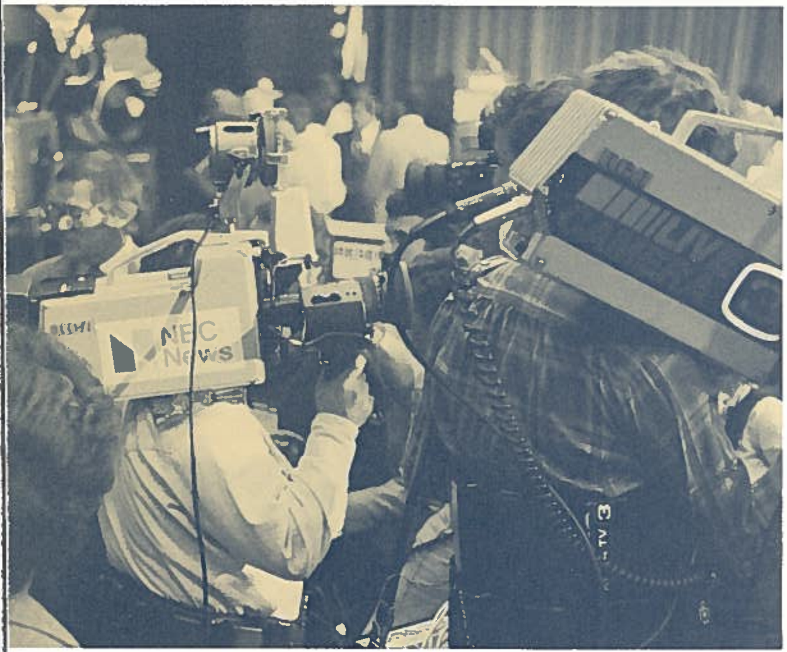
object SS-433. The distant twin quasars (0957-561A and B), which are now believed to consist of a single object whose image is split by a gravitational lens effect, were observed by intercontinental very long baseline interferometry (VLBI) for mapping purposes.

The DSN also supported radar observations of various targets. Observations of Venus were conducted to detect atmospheric absorption and possible sulphuric acid rain and to perform topographic studies. Other targets included Mercury, to determine its spin vector, and Mars, in support of ephemeris development for Galileo. The asteroid Apollo was detected by the DSN X-band radar and a measure of its rotation rate and surface reflectivity variability was obtained. The ephemeris obtained from optical observation was shown to be surprisingly accurate.



The DSN continued to support the Pioneer missions, which are managed by NASA's Ames Research Center. The Pioneer Venus mission completed the radar altimeter profile of Venus, which now covers the planet from −65 to +75 degrees. Imaging of the cloud tops, atmospheric physics, and electric fields and particle measurements are expected to continue until 1992 when the spacecraft will finally enter the Venusian atmosphere.

Pioneer 6, a solar weather station in orbit between the Earth and Venus, exceeded 15 years of operation. It is the oldest spacecraft still functioning with operating science instruments.

Pioneers 10 and 11 are still returning valuable science data from previously unexplored regions of space. Pioneer 10 is now a record 23 astronomic units (3.4 billion kilometers) from Earth, between the orbit of Uranus and Neptune. It will leave the solar system in 1987. Pioneer 11 is leaving the solar system at a slower rate and will be exceeded in distance from Earth by Voyager 1 in 1985.

Other space vehicles continuing to receive support were the last Viking Orbiter, whose mission was terminated during 1980; the remaining operating Viking Lander on the surface of Mars, which is visited once per month; and the West German solar exploration vehicle Helios.

The DSN capabilities were focused on preparation for the Voyager 1 encounter with Saturn. Radio science, VLBI, and antenna arraying were primary areas of emphasis.

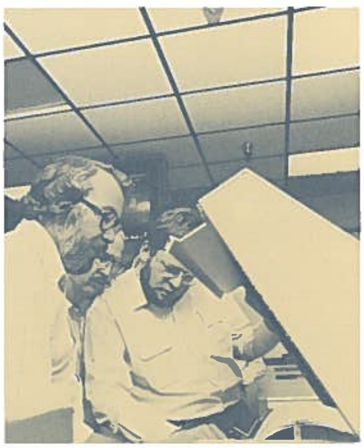
A plan to consolidate several Goddard Space Flight Center (GSFC) tracking stations

into the DSN by late 1985 matured to completion of the design phase. Within the consolidated network, the DSN will assume support for highly elliptical Earth-orbiting spacecraft formerly supported by GSFC. The design incorporates computer technology that will reduce long-term maintenance and operations costs. The design also calls for expanding the already-proven arraying capability to at least four antennas to meet the Voyager 2 real-time video requirements during the 1986 Uranus encounter.

Very long baseline interferometry is a technique for the precise measurement of angles from Earth to natural radio sources and spacecraft, with broad possibilities of application to spacecraft navigation and geodynamics. Successful demonstrations of new navigational concepts, refinements of operational procedures, and improved data flow to users were achievements during this period.

A new radio science computer facility has been established in the Mission Control and Computing Center. It comprises a central processing unit and an array processor. This facility will be used for processing radio science data from Voyager, Viking, Pioneer Venus, and future missions.

The Search for Extraterrestrial Intelligence



As part of NASA's Life in the Universe Program, JPL and the Ames Research Center are jointly developing a strategy for conducting a Search for Extraterrestrial Intelligence (SETI). Its main objectives will be to systematically test for plausible radio signals and to gather engineering data on other potential approaches to the search for signs of life elsewhere than on Earth.

The development of a SETI spectrum analysis instrument was begun. This instrument will be used with the largest existing radio telescopes, including those of the NASA Deep Space Network and non-NASA observatories, such as the Arecibo in Puerto Rico and the National Radio Astronomy Observatory facility at Greenbank, West Virginia. This activity is supported by a science working group of radio astronomers and astrophysicists.

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Earth-Orbital Projects and Experiments

An important JPL goal — the innovation of Earth-orbital projects for scientific and utilitarian purposes — is currently being achieved through the Infrared Astronomical Satellite, the Solar Mesosphere Explorer, and a wide variety of flight science instruments. Another promising future satellite mission under study is the Ocean Topography Experiment, which will chart the Earth's ocean circulation.

A combined Seasat and Landsat image of the San Rafael Swell, Utah, was produced originally in color by computing a standard Landsat color-ratio composite and using the coregistered Seasat image for intensity. The higher resolution of the Seasat radar image (20 meters vs. 80 meters for the Landsat) has the effect of sharpening the apparent resolution.

IRAS

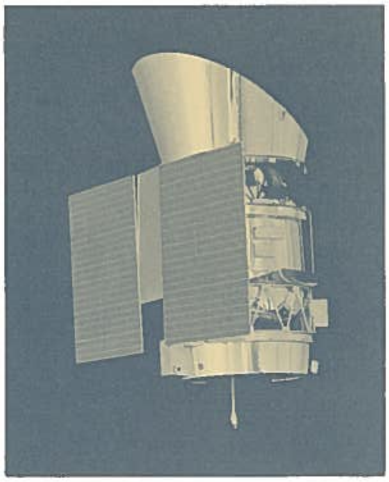
The Infrared Astronomical Satellite (IRAS), planned for a 1982 launch, will carry a cryogenically cooled, 57-centimeter-aperture infrared telescope into a 900-kilometer near-polar orbit. Before its coolant is exhausted, the international satellite will survey the sky at infrared wavelengths not observable from the Earth's surface to produce an infrared sky map and a catalog that may contain several hundred thousand new infrared sources.

JPL is responsible for project management and for the design and operation of the science data analysis facilities. Ames Research Center is responsible for developing the telescope system. The spacecraft is being built in the Netherlands, and mission control facilities will be in England. Scientists from the United States, the United Kingdom, and the Netherlands will gather at JPL to interpret the data.

By permitting scientists to study infrared objects throughout our galaxy, IRAS will contribute to the understanding of such astronomical phenomena as the origin, constitution, and replenishment of interstellar and circumstellar matter, as well as the means by which molecular clouds and stars are formed. The project will also provide insight into the problem of energy balance in ionized hydrogen regions, normal galaxies, extragalactic sources, and quasi-stellar objects.

Solar Mesosphere Explorer

The Solar Mesosphere Explorer is scheduled to be launched into a 535-kilometer Earth orbit in September 1981. The mission objectives are to determine the nature and magnitude of changes in mesospheric ozone



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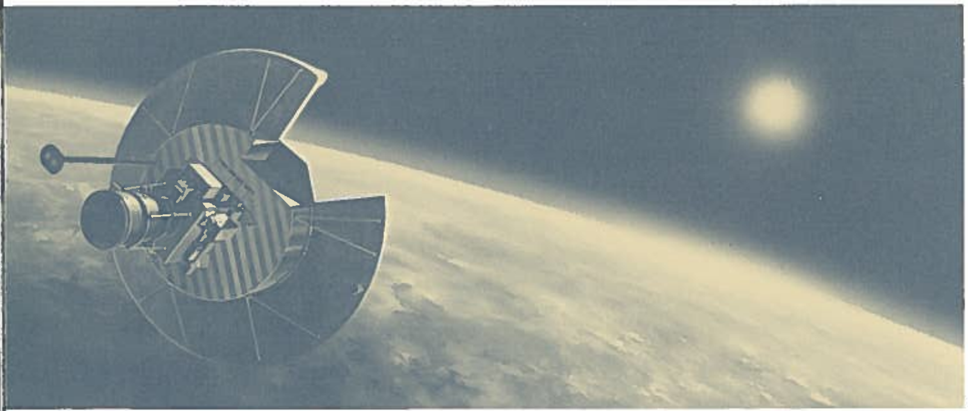


B

densities that result from changes in the solar ultraviolet flux and to establish relationships between solar flux, ozone, temperature, water vapor, nitrogen dioxide, and solar proton events.

The University of Colorado's Laboratory for Atmospheric and Space Physics has developed, assembled, and calibrated the five science instruments. Ball Aerospace Systems has developed and assembled the spacecraft. Flight acceptance testing has started on both modules, and the project is ahead of schedule.

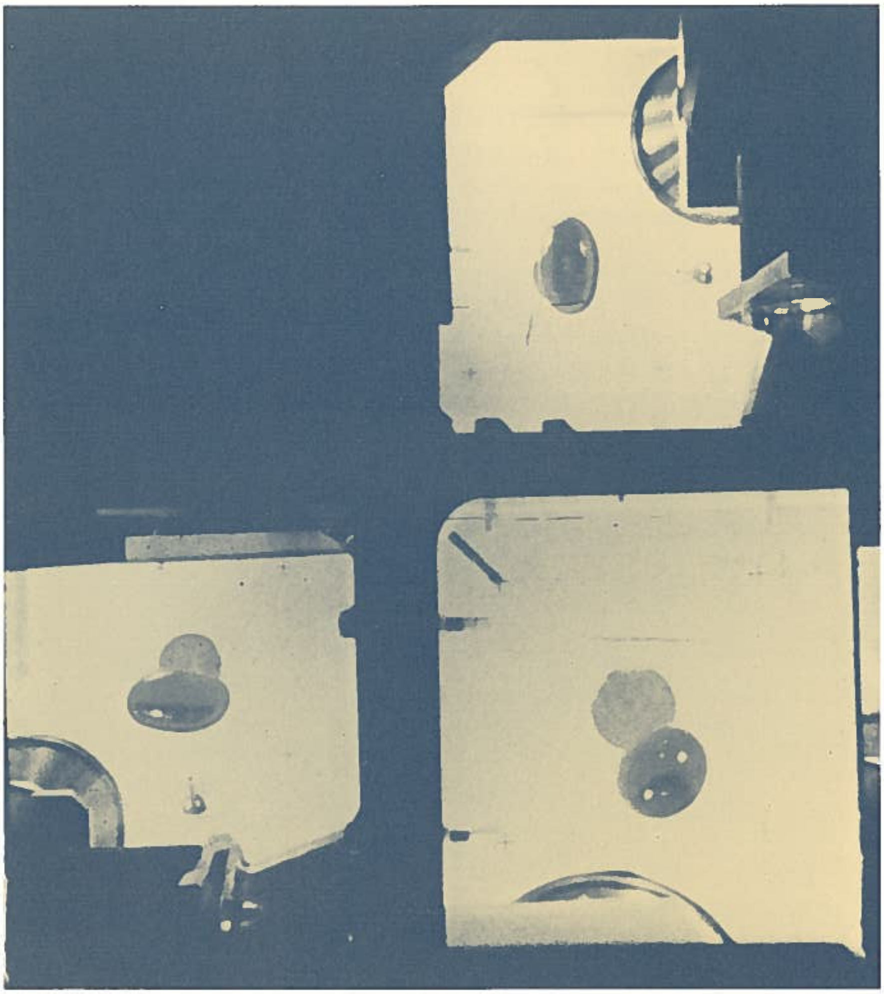
Flight Science Experiments

The Laboratory continues to be involved in a wide variety of flight science experiments carried out on missions under the overall direction of other NASA centers. This includes participation by the staff as members of science investigation teams, as well as the development of instruments.

The Laboratory is completing the design of an advanced imaging system for the Wide-Field Planetary Camera Experiment being developed by Caltech for the NASA Space Telescope Project. This imaging system, in conjunction with the 239-centimeter telescope, will be launched into Earth orbit in the mid-1980s. When this system is operational, images comparable to those acquired by Voyager seven days prior to the nearest encounters of Jupiter and Saturn will be obtainable on a daily basis. The system allows astronomical imaging observations from the ultraviolet to near infrared.

Superfluid helium will be used to cool future space experiments to temperatures below 2 kelvins. Its properties, such as thermal superconductivity, will be observed through an experiment being developed for flight on Spacelab 2. Preliminary experiments have already been performed on NASA's zero-gravity airplane.

The JPL high-resolution gamma-ray spectrometer, flown on the third High Energy Astronomy Observatory, completed a successful eight-month mission surveying the entire sky for narrowline sources of nuclear gamma-ray emission from neutron stars, black holes, and supernovae. It has made two extended surveys of our galaxy. Gamma rays from matter-antimatter annihilation, observed from the galactic center at an energy of 511 kilo-electron-volts during the fall of



C

A. *Power for the Infrared Astronomical Satellite will be provided by panels of solar arrays that convert sunlight into electricity.*

B. *The Solar Mesosphere Explorer.*

C. *A triaxial view of a liquid drop of water deployed in the JPL low-gravity acoustic module test flown twice on a SPAR rocket in 1980. These studies are adding to our understanding of nuclear physics and containerless chemical processing.*

1979, had decreased greatly in intensity by the following spring. The change indicated the annihilation must be occurring in a region less than one light year across, supporting the theory that the center of the galaxy may harbor a massive black hole.

An Active Cavity Radiometer Irradiance Monitor (ACRIM) Experiment, aboard the NASA Solar Maximum Mission spacecraft launched in February 1980, detected two large solar flux changes that were linked to specific sunspot groups in April and May. The ACRIM findings were the first direct evidence of large-scale energy storage within the convection zone of solar active regions.

A Microwave Limb Sounder Experiment for studying Earth's upper atmosphere is being developed. The experiment has been tentatively selected for flight on the Shuttle and on the Upper Atmosphere Research Satellite being considered by NASA. This experiment measures spectral line thermal emission at millimeter wavelengths from several atmospheric molecules. It will produce global maps and vertical profiles of several atmospheric parameters useful in assessing the extent to which industrial wastes may be disturbing the protective stratospheric ozone layer. A balloon version of the Microwave Limb Sounder, fabricated at JPL, was successfully test flown.

The Laboratory has completed the construction of the Drop Dynamics Module in which JPL scientists will conduct experiments utilizing the unique zero-*g* environment provided by the Space Shuttle. Experiments on a free liquid drop, successfully conducted in two rocket flights, enhanced our understanding of containerless processing in space. The free-drop studies are regarded as important contributions to nuclear physics, chemical and material processing, and meteorology. Parallel Earth-based laboratory work, conducted in neutral buoyancy tanks to simulate zero gravity, yielded new results on oscillating drops.

An infrared Fourier transform spectrometer is being developed to measure, by molecular absorption, the composition of the upper atmosphere. The Atmospheric Trace Molecule Spectroscopy Experiment will determine and measure on a global scale the volume mixing ratios of known and newly discovered molecular species. The instruments passed environmental tests in 1980. The experiments will be flown on several Spacelab missions, beginning with Spacelab 3.

Earth-Orbiting Program Planning and Earth Observation

Ocean Topography Experiment

This proposed mission would place an altimetric satellite in Earth orbit for five years to determine the variable and mean oceanic circulation and the height of the ocean surface on a global basis. The Ocean Topography Experiment Science Working Group recommended the mission to NASA as a major contribution to oceanography in the fields of circulation and tidal action, a sophisticated follow-up to the Seasat flight, which accumulated oceanographic data in 1978.

Seasat Data Utilization

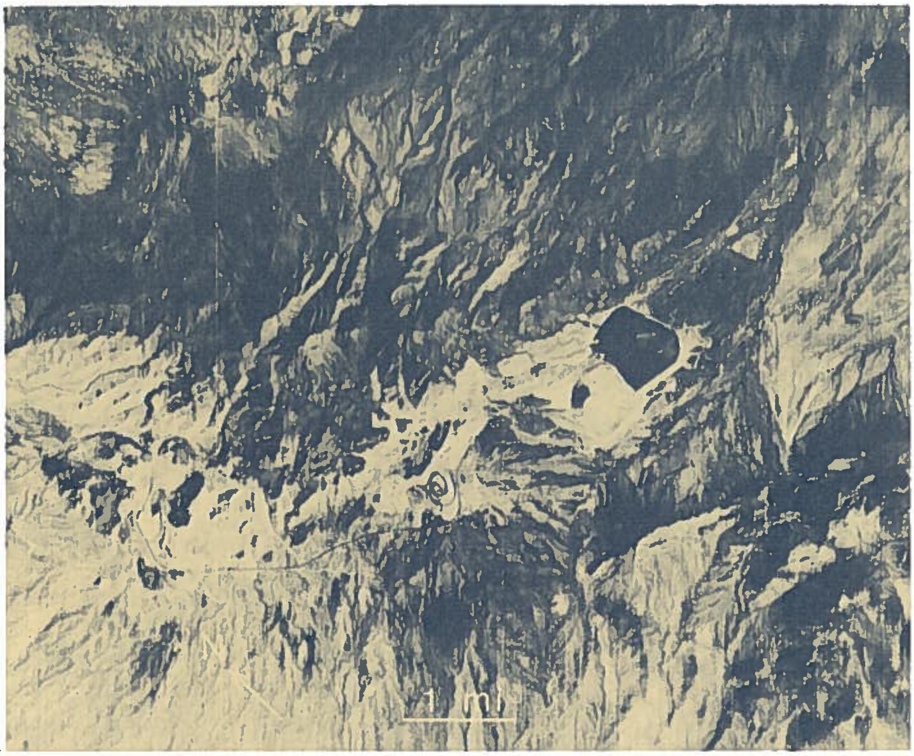
Sea-surface measurements made by the Scanning Multichannel Microwave Radiometer aboard the 1978 Seasat agreed to within one degree with nearly 100 observations taken at the surface. The accuracy of these results was established over a wide range of sea-surface temperatures (10 to 30 degrees Celsius). Wind-speed measurements also showed close agreement to within 2 meters per second with extensive ground-truth data. Comparisons were made in four geographical areas: the northwest Pacific, the Gulf of Alaska, the tropical western Pacific, and the western Atlantic near Bermuda.

Seasat–Landsat Geological Imagery

To develop geological remote sensing techniques for resource exploration, a Seasat radar image and a Landsat multispectral image of the San Rafael Swell in eastern Utah were superimposed or coregistered by JPL's Image Processing Laboratory for an investigation conducted by the Radar Remote Sensing Team.

The San Rafael Swell study area is a breached anticline (upfold) composed of a variety of sedimentary rock types such as sandstone and shale. The area is roughly 100 kilometers long and 50 kilometers wide. Economically significant deposits of uranium occur in some of the sandstone formations. The simple geologic structure and arid climate make the area an attractive geologic test site.

A



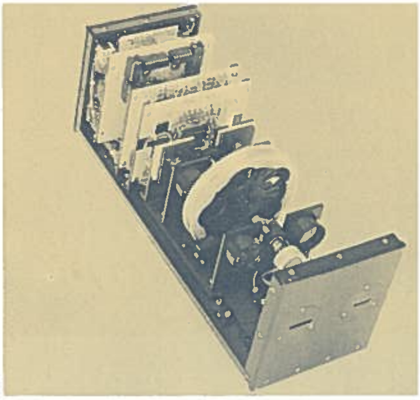
A. A thematic mapper simulator produced an image that successfully identified rocks associated with copper deposits near Tucson, Arizona. The original image of the Silver Ball deposit area was in color, and orange-yellow shadings indicated rocks associated with copper deposits.

B. The Ocean Topography Experiment Satellite would chart the Earth's ocean circulation.

Because the imaging systems of Seasat and Landsat sample different properties of the Earth's surface, a combination of data from the two systems will allow better rock discrimination than either alone.

NASA/*Geosat Test Case Project*

Oil and mining company geologists are cooperating with JPL scientists in this project to evaluate remote sensing techniques for locating oil, gas, uranium, and copper deposits. A thematic mapper simulator — a forerunner of a scanner to be flown on a future Landsat satellite — has been successfully tested in an aircraft. Copper deposits near Tucson, Arizona, were delineated by the spectral response.



C

Experiment Development

Hand-Held Ratioing Radiometer

This instrument can be used by a lone field investigator to characterize rocks and minerals. It simultaneously measures surface radiance in several spectral bands, and displays the ratio in a digital readout.

Developed at JPL, the dual-beam radiometer can be used on the ground or from a moving vehicle or aircraft, and holds promise for furthering mineral and petroleum exploration. Barringer Research Inc., Denver, Colorado, has received a license from Caltech to manufacture the instrument.

B

Multispectral Mapping Radiometer

An advanced Landsat imaging system, using spectrally dispersive optics along with area array detectors, will provide spectral data in perfect registration. The JPL concept would cover 60 spectral bands including visible, near infrared, and infrared frequencies. A technology development program was begun to develop optics, detector arrays, the focal plane assembly, and the data-handling electronics.

C. In-situ use of the Hand-Held Ratioing Radiometer can provide timely spectral characterization of rock samples without returning them to the laboratory for X-ray analysis, which is expensive and time consuming.

Advanced Microwave Sounder Unit

This 20-channel temperature and humidity profile radiometer, being designed and developed by JPL for the National Oceanic and Atmospheric Administration spacecraft, is a more sophisticated version of the 4-channel units on NOAA weather satellites.

Energy and Energy Conversion Systems

The tempo of JPL activities in the energy sector continued brisk under the aegis of JPL's Energy and Technology Applications Office and the U.S. Department of Energy. While solar energy technologies dominated, important research and development tasks also were performed in transportation, coal, and alternative fuels areas.

Solar Energy

Photovoltaics

As lead center for DOE's photovoltaic technology development program, JPL brought on line several major applications experiments: A 100-kilowatt system at the Natural Bridges National Monument, Utah; two residential test homes in Arizona and Florida; and a residential test center in Massachusetts. Current design efforts are concentrating on dc/ac inverters for residential applications of solar cell technology.

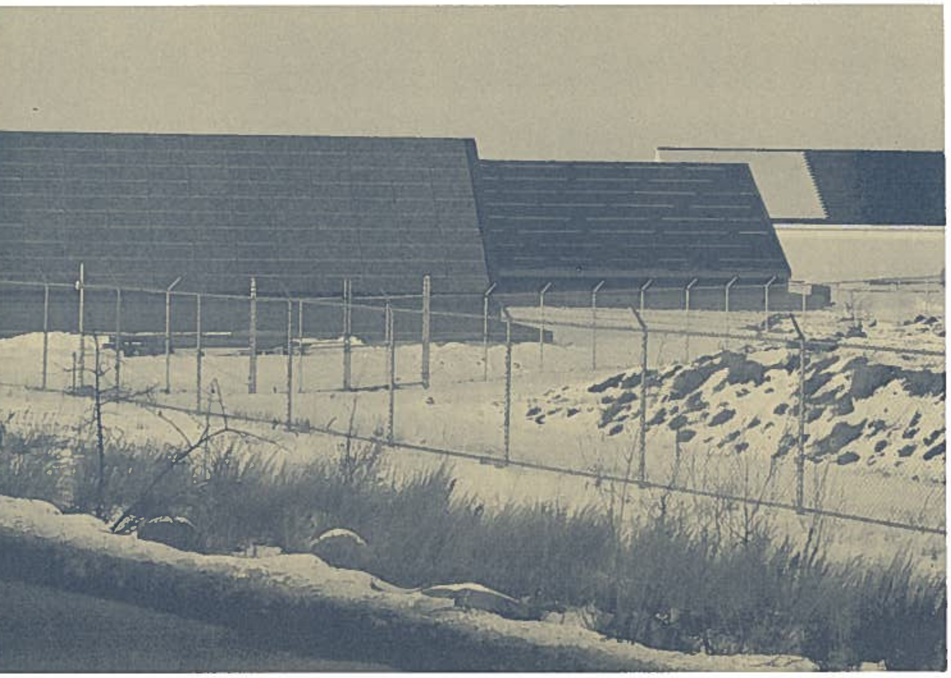
In the program planning area, a central-station concept was formulated to encourage earlier conversion to solar cell technology by utility companies now dependent on oil or gas. This potential market may be attainable at system prices of about $1.60 per peak watt, a study indicated. Plans for an applications experiment were begun.

The Low-Cost Solar Array Project, in its sixth year of cooperative effort with industry, reported production efficiency increases in flat solar cell modules and silicon ribbons and ingots. (Silicon is the main ingredient in solar cells.) An economic analysis indicated that, at the present rate of progress, photovoltaic modules could be marketable in large quantities at a reasonable cost in three years. Private industry invested $100 million in photovoltaics in 1980 and total sales were estimated at $40 million, mostly for nongovernmental applications.

The 100-kilowatt photovoltaic power system at Natural Bridges National Monument, Utah.

Solar Thermal Power Systems

Another major technology effort, also sponsored by DOE, is the development of solar ray point-focusing modules and systems capable of producing electricity or process heat. Prototype thermal receivers and power converters are being tested on two 11-meter test-bed concentrators at the Parabolic Dish Test Site at Edwards Test Station on the Mojave Desert.



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Continuing tests are being conducted on industry-supplied components, subsystems, and collector modules. The first of these evaluated an OMNIUM-G module built in Orange County, California. Solar thermal equipment from manufacturers throughout the nation has been scheduled for testing, including three steam engines, one Stirling engine, and several receivers and power converters.

One steam receiver was used to manufacture furfural, a dehydrogenated alcohol. Another receiver, a ceramic type built in New Hampshire, achieved exhaust air temperatures of 871 to 1427 degrees Celsius.

Negotiations were begun to perform tests of commercial parabolic dish concentrators at the test site in 1981.

Solar Pond Technology

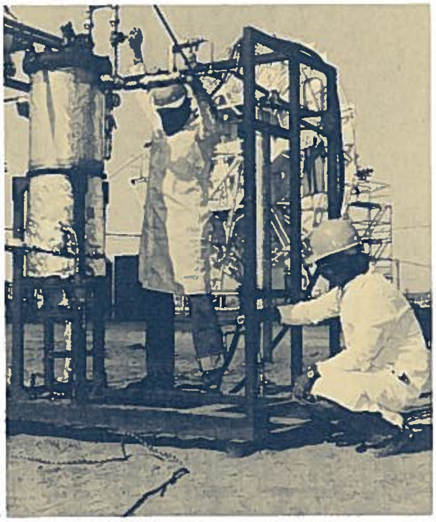
A joint project is under way with Southern California Edison Company, the California State Energy Commission, DOE, and Ormat Turbines of Israel to demonstrate salt-gradient solar pond technology at the Salton Sea. Concept and feasibility studies will be completed by JPL in 1981. If these are positive, construction of a 5-megawatt plant is scheduled to start in 1982. If the test plant succeeds, construction will begin in 1985 on a commercial 600-megawatt plant.

The process relies on using the thermal energy of near-boiling, high-salinity water that concentrates at the pond bottom. In heavily brined ponds, this heat energy can be extracted to drive an electric turbine system that generates usable electric power.

Utility Systems

This program develops and evaluates concepts for integrating alternative energy sources into electric utility power systems, and reducing overall energy needs. A DOE-sponsored task force made two studies of the communications and control techniques that would be required. Another project, sponsored by NASA, identified JPL capabilities, such as image processing, that could be used to meet utility planning needs.

An electric power system simulator was completed and demonstrated extensively to utilities. It is being used to help in the evaluation of future energy options. A specific



B

task for Southern California Edison is to determine the effects of conservation technologies on utility power loads.

Geothermal

Extensive field tests of a helical screw expander (HSE) power system for geothermal energy were conducted by JPL at Cerro Prieto, Mexico, following earlier operation at Roosevelt Hot Springs, Utah. The HSE power plant has now operated over 1,500 hours and produced over 175,000 kilowatt hours of energy. The project is funded by DOE.

The unit is scheduled for testing in 1981 in Italy. Manufactured by Hydrothermal Power Company, the plant comprises two intermeshing helical screws that accept hot, untreated brines directly from the geothermal wellhead. The power plant is driven by the steam produced from the hot liquid as it decreases in pressure during its passage through the machine.

Coal Systems

The JPL coal program, sponsored by DOE and NASA, includes work in mining technology and other aspects of coal utilization. A requirement analysis for an advanced underground mining system was completed, with design suggestions stressing safety and production cost reduction.

A JPL chlorinolysis project involved test experiments that indicated a water wash instead of expensive organic solvents could be used effectively in the process of removing sulfur from coal. The JPL chlorinating system may increase the potential of removing up to 90 percent of the sulfur from some bituminous coal at extremely high temperatures (500 to 700 degrees Celsius).

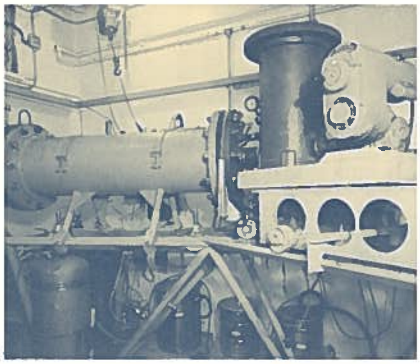
A. The Northeast Residential Experiment Station in Massachusetts.

B. A small-scale demonstration unit for the production of furfural is now in operation; in the background is the 80-kilowatt test bed concentrator.

Transportation Systems

Electric and Hybrid Vehicles

An advanced electric passenger car developed under DOE contract by Garrett Corporation was received at JPL for testing late in 1980. This car, designated ETV-2, employs a highly complex flywheel storage system. Another test vehicle (ETV-1) produced by General Electric and Chrysler has achieved most of its goals. Presently available commer-



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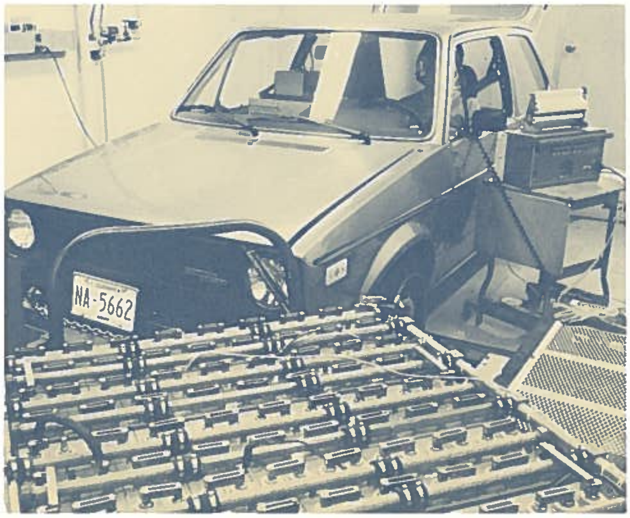


B

A. The continuous-flow, mini-pilot desulfurizing plant chlorinator can process 2 kilograms of coal per hour.

B. The Westinghouse nickel-iron battery connected to the South Coast Technology electric Rabbit during dynamometer testing.

cial electric vehicles from four manufacturers were also tested. A near-term hybrid car, containing both an internal combustion engine and an electric motor, is under development by General Electric and Volkswagen for DOE and JPL.

Advanced lead-acid and nickel-iron batteries were tested in several vehicles, using the JPL dynamometer laboratory and a test track at Edwards Test Station.

A JPL computer program was formulated, enabling nationwide users to simulate performance of vehicles and components including batteries, motors, and transmissions.

Diesel Engine Emission Research

An electrical discharge technique pioneered by JPL proved successful in destroying agglomerated diesel fuel particulates in laboratory tests. The next projected step is to show the feasibility of using a discharge device on the exhaust system of truck and automobile diesel engines. A prototype device is being built for testing and gathering data to determine the biological and health benefits it may afford. Funding for the diesel particulate emission work comes from DOE and the California Air Resources Board.

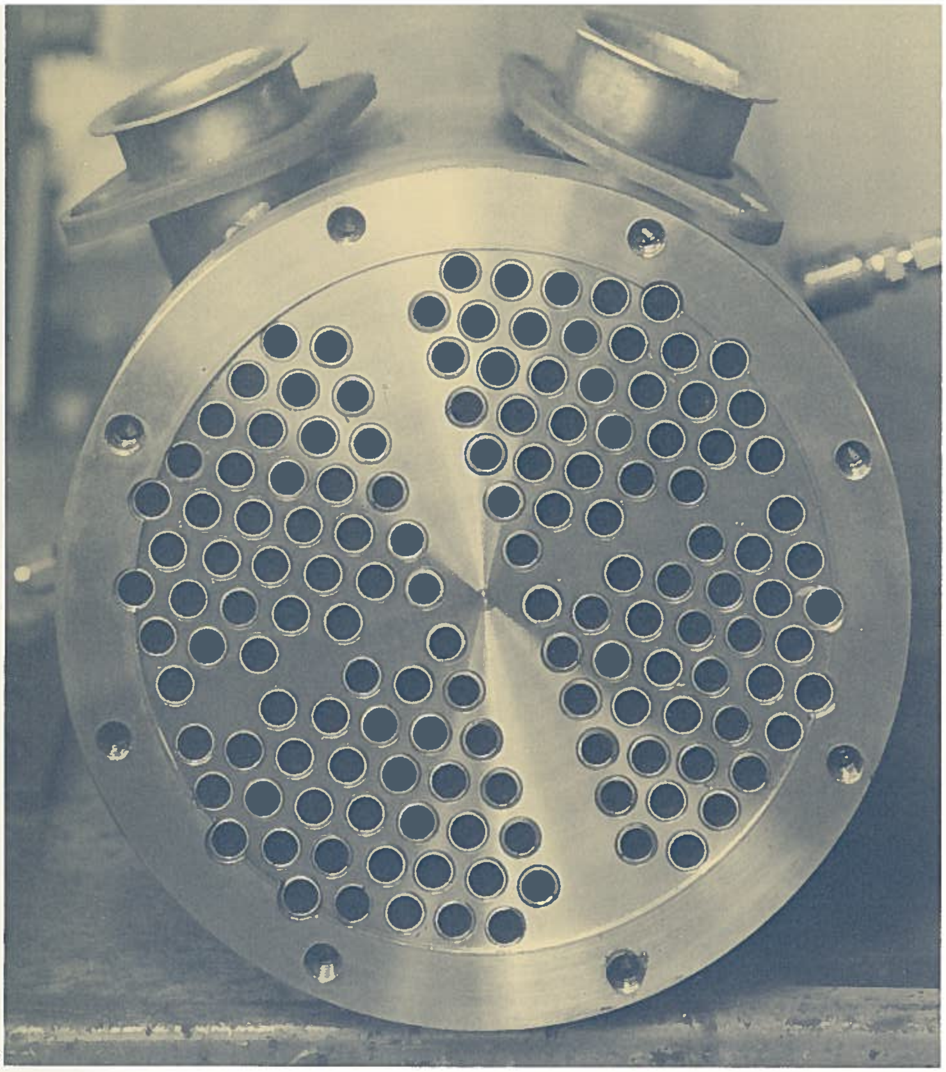
Methanol Decomposition

A compact reactor was built at JPL to demonstrate a concept for using methanol in internal combustion engines. Methanol, a liquid alcohol, is a promising alternate fuel for transportation. The reactor catalytically converts the alcohol into a hydrogen-rich gas by using the exhaust gas of the engine to supply the heat of decomposition. Resulting leaner mixtures coupled with higher compression ratios could improve fuel economy and reduce emissions. The reactor will undergo vehicle road testing in 1981.

Antimisting Fuels

Under a joint United States–United Kingdom program, JPL is developing antimisting fuel technology to reduce the postcrash aircraft fire hazard. The U.S. portion of the program, cofunded by NASA and the Federal Aviation Administration, seeks to provide the FAA with scientific data and new technology.

Initial experiments show that the mechanism that prevents mist formation and its ignition during a survivable crash-landing is related to development of high-tensile viscosity, which is a physical antimisting characteristic inhibiting breakup of the fuel. Image enhancement techniques were used to quantify fuel breakup in such terms as fuel loading, droplet size, and cumulative particle distribution. The same space-derived technique will be used to assess the fire suppression ability of various polymers.



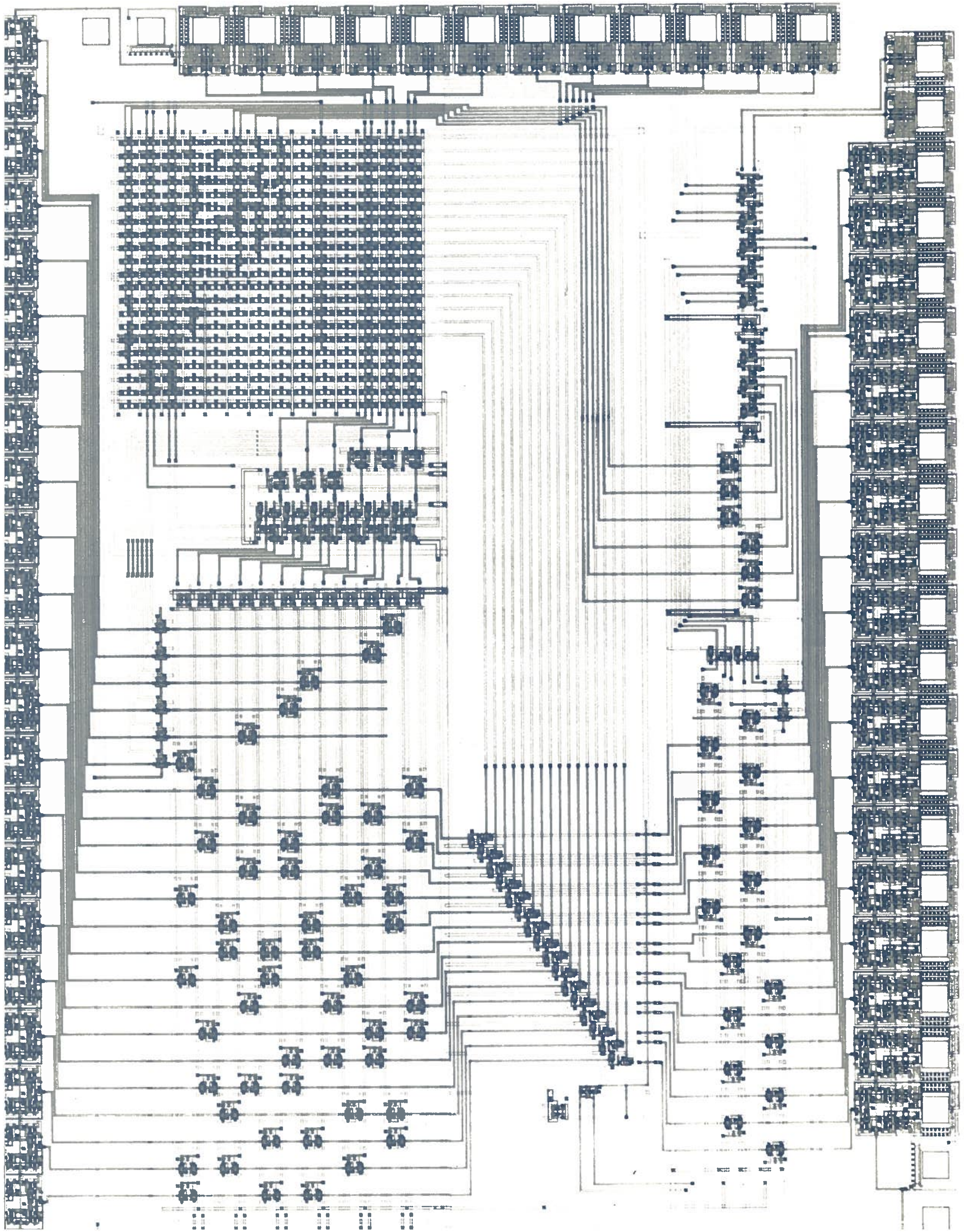
C

D

C. The conversion of alcohol into fuel gas takes place within the catalyst-loaded heat transfer tubes of the methanol reactor.

D. ETV-1, under test on the JPL dynamometer, demonstrated that electric vehicles can be a viable and desirable transportation option.

Technology



This large-scale integrated check-plot for a fault-tolerant computer system memory interface was produced by running a standard computer program on a JPL-created computer file. The same technique can be used to make magnetic tapes for the commercial production of masks. The actual size of the fabricated chip is 3.9 × 4.7 millimeters.

Research and development in both space and nonspace applications are vital concerns of JPL. The broadening scope of these interests includes tasks in such fields as biomedicine, oceanography, and ecology. Two projects in applied technology are also under way for the Army and the Air Force.

Large-Scale Integration Design/Fabrication

The Laboratory began a program for engineers and designers interested in improving and further miniaturizing the integrated circuits aboard spacecraft. Patterned after a Caltech computer science course, the program has as its goal an efficient interface between the latest design methods of large-scale integration (LSI) and industrial fabrication of the circuits.

Basically, the program seeks to reduce complex circuit-board circuitry to chip size. Eight projects were designed and fabricated; preliminary tests of the resultant chips indicate a high degree of success. The program marked the start of a JPL internal LSI custom-design capability.

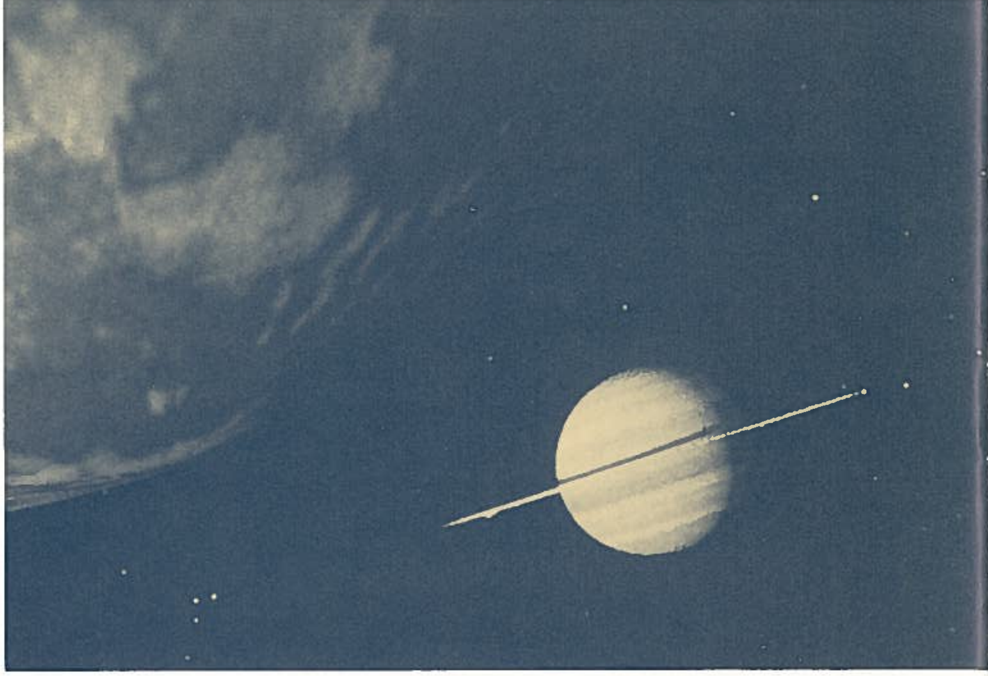
Semiconductor Interface Research

The performance and reliability of LSI semiconductors are determined largely by the chemical and electrical properties of the interface region. Intensive JPL studies of this interface used high-resolution X-ray photoelectron spectroscopy, new chemical profiling techniques, and a variety of electrical probes. These studies showed the atomic interface to be considerably different from the model previously used in the semiconductor community. The principal finding of this work is an abrupt, one-atomic-layer transition between silicon (Si) and silicon dioxide (SiO_2), with several atomic layers near the interface exhibiting strained Si-O-Si bonds. This structure at and near the interface is sensitive to the fabrication process, and has been correlated to the susceptibility of devices to radiation exposure, such as that encountered in space. The findings have prompted a continued effort, in collaboration with other laboratories, to seek a more precise method of achieving radiation hardened LSI semiconductors.

Computer Vision for Autonomous Systems

A computer vision system designed for control of robots and other autonomous systems is being developed for space, laboratory, and possible industrial use. It comprises two solid-state television cameras mounted on an electric pointing platform, computer electronics, and related software. It can identify objects and their positions relative to each other in a given scene, and provide data on velocity and attitudes.

The system has been used for solar panel assembly in the laboratory and appears to presage a cost-effective means of faster automated assembly.



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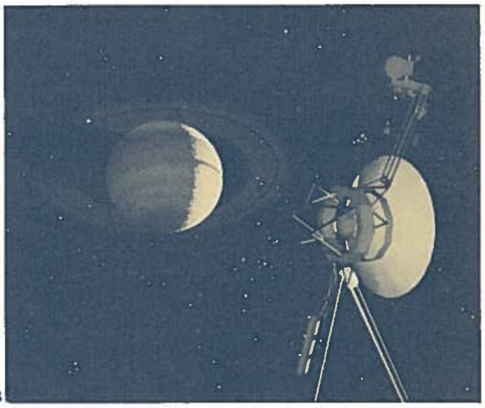
Computer Graphics

The Computer Graphics Facility is recognized as a leader in its field. Notable among achievements this year were widely used films simulating Voyager encounters with Jupiter and Saturn, and animated portions of the Cosmos series on public television. The realism of the films would have been impossible using conventional animation techniques. JPL specialists have developed the computer hardware and software systems since the establishment of the facility in 1976. The software system includes the precise motions, locations, and brightnesses of the planets and their satellites, and of stars down to the sixth magnitude to allow their correct depiction on each frame of film.



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Deep Space Exploration Support

DSN *Advanced Systems*

The DSN Advanced Systems Program continued to develop and demonstrate technology to support future deep space exploration. Missions to the far regions of the solar system are likely to require a ten-fold improvement in spacecraft navigation and telemetry capabilities. Efforts are underway to provide improved performance for less cost in the areas of navigation, radio science, telemetry, and command.

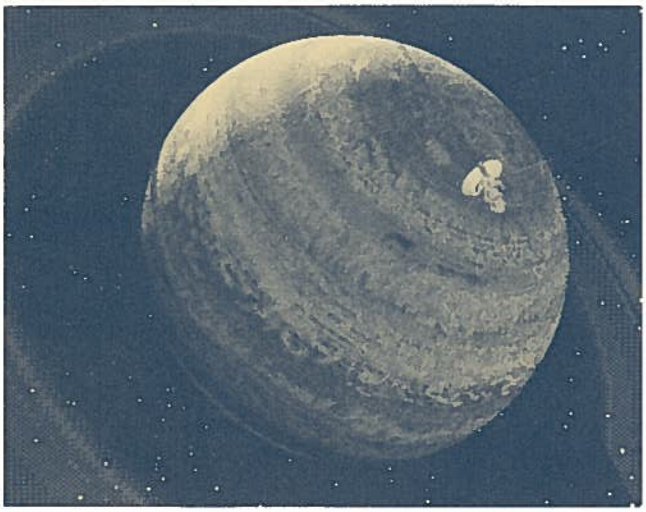
One navigation technique has the potential for providing improved spacecraft position measurements in a fraction of the tracking time now required. The method, Delta Differential One-Way Ranging, uses extragalactic radio sources such as quasars to get an angular fix on spacecraft position. Experiments conducted with the Voyager 1 and Voyager 2 spacecraft demonstrated the concept feasibility and provided direction for further system development.

Navigation and radio science require reliable and ultrastable clocks and time distribution systems. Future missions will require tenfold improvement in current state-of-the-art atomic frequency standards. Several methods of improving stability are being studied. The goal is to develop an oscillator and an ultrastable frequency distribution system that can operate automatically and reliably. Optical fiber communication links are being investigated for stable transmission of time and frequency within a clustered complex of DSN stations. A 3-kilometer fiber optic test link has demonstrated stabilities of a few parts in 10^{16} over 1000-second averaging times. Further improvements are anticipated.

Higher transmission frequencies offer potential major improvements in telecommunication link performance. Uplink transmissions for Voyager were made at S-band frequencies of 2.1 GHz. An automatically operated X-band transmitter now under development would permit future 20-kilowatt transmission at 7.2 GHz. The higher frequency is expected to improve navigation and radio science capabilities. The X-band uplink will also permit deeper penetration of the solar corona and extend spacecraft command capability to within one degree of the Sun, vital to such missions as Starprobe. The X-band uplink system will undergo experimental tests in 1981 at Goldstone.

Advances in antennas and in receiving system designs promise improved deep space telemetry reception. A single concentric feed under development will provide broad-band reception at both S- and X-band frequencies. Broad-band low-noise reception will be further enhanced by a cryogenically cooled receiving system, consisting of S- and X-band parametric upconverters and a K-band maser amplifier. This system will permit simultaneous reception of S-, X-, and K-band signals with bandwidths of hundreds of megahertz.

To reduce outside radio frequency interference (RFI) at Goldstone and other DSN stations, a portable system for RFI detection was devised and tested. The system analyzes the S-band spectrum over a 300-MHz

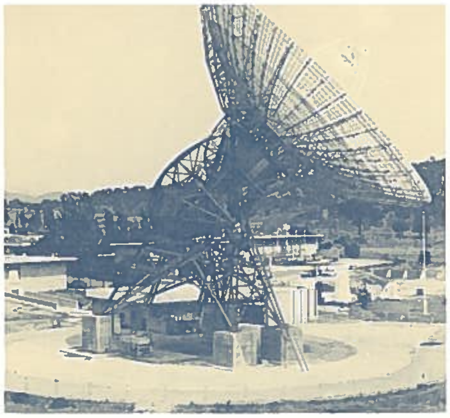


C

D

Before Voyager gave us accurate knowledge of Saturn's appearance, a computer-graphic artist, working with then-current data, used a computer screen as his empty canvas and a computer program as his palette and brush to create these views of (A) the planet as seen by Voyager at close encounter with Saturn's largest moon, Titan; (B) and (C) the spacecraft's approach to the planet.

D. This optical fiber is being spliced by welding with an electric arc.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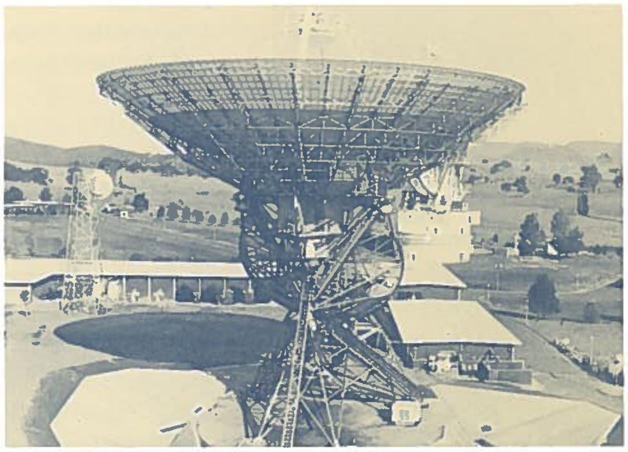
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C

A. The 26-meter S-band antenna at Madrid, Spain, and B. an identical antenna at Canberra, Australia, were converted to 34-meter S- and X-band antennas. These conversions were necessary because X-band telemetry, which offers a potential factor of 10 data-rate increase over S-band, is becoming the standard telemetry frequency.

bandwidth with a resolution of 305 Hz. The detection system will be used and analyzed in 1981 at Goldstone.

Earth Crustal Dynamics

The ARIES project continued measurements of Southern California episodic crustal motions, which corroborated geodetic measurements by the U.S. Geological Survey. ARIES is an acronym for Astronomic Radio Interferometric Earth Surveying.

This research has been underway to develop the use of radio interferometry at microwave frequencies for determining three-dimensional Earth positions with an accuracy of a few centimeters over baselines of 180 to 500 kilometers. As a result, the design and construction of an operational mobile interferometer have been initiated. This work is conducted under a project called Operational Radio Interferometry Observing Network (ORION).

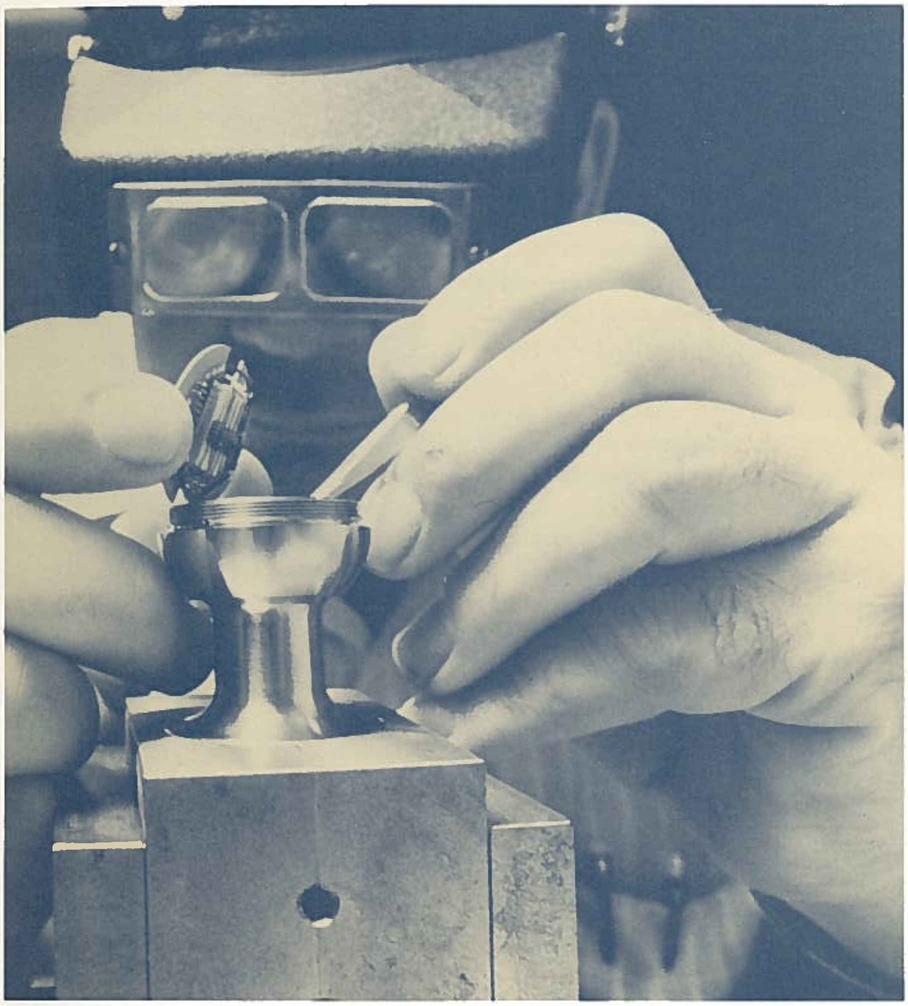
Biomedical Technology

Hip-Joint Replacement Biotelemetry System

Of the 100,000 total hip-replacement operations performed annually in the United States, prosthetic loosening resulted in a failure rate of up to 54 percent in five years. JPL, in collaboration with the UCLA Division of Orthopaedic Surgery, has an ongoing effort in telemetry microminiaturization for assembly into a total hip prosthesis. Assembly of two fully instrumented engineering model prostheses has been completed. Further testing at UCLA will lead eventually to implantation in humans in perhaps three years. Because these systems receive power through extracorporeal induction, they will provide monitoring data over extended periods of time. These data will lead to a better understanding of hip action and to improved designs in prosthesis.

Ceramic Surface Joint Replacement

In collaboration with the UCLA Division of Orthopaedics, JPL has been carrying out research on sialon and alumina cermets for use in surface replacement hip prosthesis that would not require acrylic cement for fixation. Current canine tests with sialon have been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halted in favor of alumina. The friction and wear tests indicated comparable low polyethylene wear rates for the high-quality surface finishes. Previous studies reported that polyethylene wear against alumina was as much as twenty times less than that for conventional alloys. Biocompatibility and bone ingrowth studies are continuing to validate the material. Additional research to understand and control the fabrication process will be continued under National Institutes of Health sponsorship.

Magnetic Cell Sorter

Immunomicrospheres are specially designed microscopic particles that have antibodies or similar molecules chemically bound to their surface. Research at JPL has developed methods to synthesize these microspheres so that they incorporate magnetic compounds. These magnetic immunomicrospheres can then be used to selectively label cells that have antigens on their surface, antigens that fit the antibodies used in microsphere synthesis.

With funding from the National Cancer Institute and NASA, JPL has developed technology to make use of this magnetic cell labeling to separate subpopulations of cells from one another. This method can be used on cell types that cannot be separated by more conventional means, and provides a new resource for many fields of research in cell biology mechanisms. This technology has been licensed to a major laboratory instrumentation firm.

Electro-Optical Ion Detection

For several years, JPL has been developing a novel ion detector for use in mass spectrometry, an effort funded by the National Institutes of Health and NASA. This detector, which combines technologies in fiber optics and electronic image intensification, has, in the last year, demonstrated levels of sensitivity, resolution, and mass range unattainable in any other single mass spectrometer.

Plans are under way to provide Caltech researchers with a mass spectrometer system using this detector and a solid-state gas-phase peptide sequencer. The system is designed to study the sequence of amino acids in peptide molecules. Potential environmental uses include detection of toxic gases

C. A mobile 9-meter ARIES antenna used in conjunction with two stationary reference stations to take geophysical measurements.

D. The end cap of this engineering model of a hip-joint prosthesis has been removed to reveal the telemetry elements that will monitor hip-joint loads and forces.

in work places and survey of industrial waste sites for evidence of dangerous conditions.

Undersea Technology

A JPL unmanned submersible, called the Advanced Ocean Technology Development Platform, passed engineering tests in Long Beach harbor. The towed, side-looking sonar system is being developed for National Oceanic and Atmospheric Administration tests in the Atlantic in mid-1981.

Another oceanographic application of space technology, the JPL conditional sampler, controlled the data collection of instruments on the five-kilometer-deep ocean floor off Nova Scotia in the High-Energy Benthic Boundary Layer Experiment conducted by the Woods Hole Oceanographic Institution.

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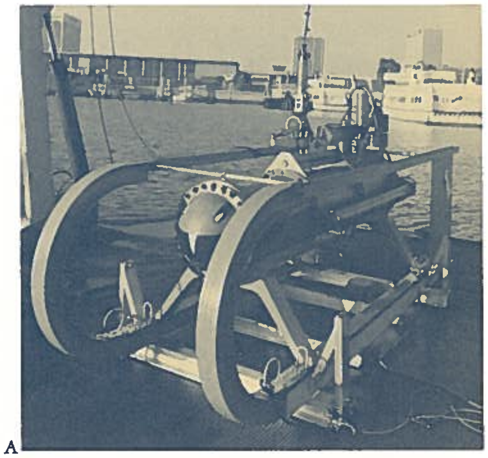


Ecology Systems

Closed or controlled ecology life support systems will be necessary if man is to fly long space missions or establish colonies on other planets. JPL has been studying waste management and synthetic food production for such systems. In June 1980, experiments were begun with plant and animal communities hermetically sealed in laboratory flasks. These communities contain crustacea (shrimp), algae, and microorganisms in brackish water. Many of these closed microsystems were thriving at year's end. All materials within the flasks are recycled through the systems; solar radiation is the source of energy.

Early findings are that the algae vary in evolutionary development as the ecosystems age, and that internal pressure within the systems is increasing gradually. Means of monitoring physical, chemical, and microbiological changes within the systems are being explored.

A. The JPL unmanned towed submersible is designed to explore and map the ocean floor to depths of 6095 meters.

B. Hermetically sealed flasks containing crustacean, algal, and microorganismic ecosystems in synthetic sea water.

Mobile Automated Field Instrumentation System

Instrumentation study and development work begun in 1979 for the U.S. Army Training and Doctrine Command Combined Arms Test Activity evolved last year into the Mobile Automated Field Instrumentation System (MAFIS) Project. MAFIS is an instrumentation system that will enable large-scale, force-on-force simulated battlefield exercises to be monitored and evaluated. All combat elements (including foot soldiers, tanks, and helicopters) will be instrumented with weapon simulators and detectors; a field element will calculate position location and engagement information and transmit data to a command and control center. The simulated battlefield coverage area will be 50 x 50 kilometers; the system is designed to be transportable to any location.

In October 1980, agreement was reached with the Army on a MAFIS I project, and implementation is proceeding. MAFIS I will consist of 200 universal field elements, a position location network, a communications network, and a command and control center, all integrated and delivered as an operational system by the end of 1985. The system must be designed for expansion to over 1,000 universal field elements.

JPL will provide the system design and the technical management for MAFIS. System contracts for the production of the universal field elements will be directed by JPL.

Autonomous Spacecraft Project

Work was initiated on a new project for the Air Force Space Division to achieve by the end of the decade a high degree of defense satellite autonomy and independence from ground stations. The implementation of certain autonomy features on planetary spacecraft, necessitated by the long two-way communication times, has resulted in the development of a unique set of JPL skills with direct application to this national defense need.

The autonomous spacecraft project will expand this technology base through (1) the development of autonomous design and validation methodology; (2) the application of this methodology to selected Air Force spacecraft; (3) critical subsystem-level autonomy demonstrations; and (4) a system-level demonstration. This project will be conducted over a 5-to-6-year period and will rely heavily upon JPL's experienced manpower; contractor support will be used in subsystem fabrication or modification.


B

Three executive committees were established by the Director to address Laboratory concerns and future needs: the Space Science and Exploration Executive Committee (SSEEC), the Utilitarian Programs Executive Committee (UPEC), and the Institutional Executive Committee (IEC). The SSEEC provides management overview and coordination of JPL activities in space science and exploration, including extra-solar-system investigations using instruments located on or above the Earth. The UPEC provides management guidance and coordination of utilitarian programs, including Earth observations from space, energy, defense, and such technology applications as geodynamics and biomedical engineering. The IEC is responsible for overview, coordination, and integration of planning and control activities in institutional matters affecting more than one program or organizational area.

Planning and Review

The Office of Planning and Review supported the Director's Office in a variety of administrative, planning, assessment, and review functions. Among these are administration of reliability and quality assurance for Laboratory programs, administration of the Director's Discretionary Fund, and JPL relations with the Caltech President's Fund.

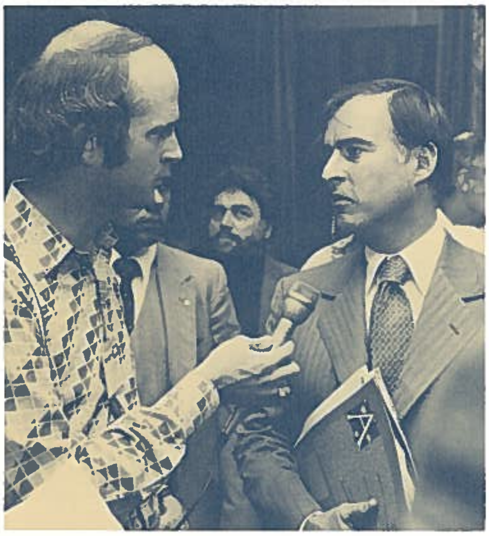
Formal Reviews

All work output and all proposals for new work are reviewed for quality and consistency with JPL objectives and commitments. Formal reviews are conducted when the work activity or proposal involves large costs or highly visible deliveries, or when it affects important future assignments or institutional policies.

During fiscal year 1980, 47 formal reviews were conducted, 15 for the Flight Project Office, 6 for the Telecommunications and Data Acquisition Office, 5 for the Energy and Technology Applications Office, and 21 for the Technology and Space Program Development Office.

Director's Discretionary Fund

The Director's Discretionary Fund (DDF), established in 1969, is documented by a



NASA–Caltech memorandum of understanding. The fund provides resources for independent research and development in promising fields of science and engineering. It emphasizes innovative and seed efforts, and encourages collaborative work with faculty and students at Caltech and other universities. Potential for follow-on funding from other sources is one criterion in selecting tasks for DDF support. From an initial level of $400,000 per year, which prevailed through 1975, the fund has been increased by NASA in three steps to $1,000,000 annually, beginning in 1980.

Proposals for DDF funding are solicited annually, and the response in terms of worthy proposals usually far exceeds the resources available. At the close of fiscal year 1980, 192 tasks had been funded by the DDF since inception, and 34 tasks were active. It is expected that about 30 new tasks will be initiated in the 1981 program, selected from some 110 proposals so far considered.

Work conducted under DDF sponsorship during 1980 included:

1. A study of solar oscillations (with USC, UCLA, and Mount Wilson Observatory).
2. A new instrument concept in gamma-ray astronomy (with Caltech campus).
3. A feasibility study on the direct detection of planets around other stars using telescopes in space (with the University of Arizona and Georgia State University).
4. Automatic focusing for the correlation of synthetic aperture radar imagery (with the University of Kansas).
5. Analysis of the structure and interaction of galaxies using image processing techniques (with Mount Wilson Observatory).
6. Evaluation of various graphite-fiber composite materials in improving high-energy density lead–acid batteries.

Caltech President's Fund

The NASA–Caltech memorandum of understanding also provides for the Caltech President's Fund (PF) which also encourages collaborative efforts between JPL staff and faculty and students of Caltech and other universities. On a matching basis, NASA contributes up to $350,000 a year to this fund.

Twenty PF tasks in 1980 involved such schools as the Universities of Arizona, Chicago and Utah, three campuses of the University of California, Stanford, and Cornell.

The Office of Patents and Technology Utilization evaluates, patents, and publicizes as warranted the many inventions and technological innovations resulting from JPL work. In 1980, a record 367 inventions and innovations were disclosed to NASA and other sponsors of JPL.

The U.S. Patent Office issued 55 patents to Caltech and NASA for JPL inventions. The JPL Office also provided selective licensing assistance to 45 other previous Caltech-held patents, issued or pending. Caltech's record of licensing one-third of its patented JPL inventions was maintained.

The JPL office described 141 inventions and innovations in NASA's *Tech Brief Quarterly*, and also mailed technical information documents in response to more than 28,000 inquiries about JPL inventions.

Two UNIVAC 1100/81 computers were installed to support flight projects and hundreds of general computer requirements as a substantial part of updating JPL's information and data processing systems. The computer replacement project is expected to be completed in the next year with integration of the mass storage system and high-speed data network, and the installation of a third UNIVAC 1100/81.

A Distinguished Visiting Scientist Program, initiated by the Director in 1979, continued to provide eminent authorities for short-term consultation on important JPL projects. They are Professors Klaus Hasselmann, Germany; Jacques Blamont, France; Michael S. Longuet-Higgins, England; and Eugene Shoemaker, Richard Goody, and Klaus Keil of the United States.

Under a Faculty Fellowship Plan sponsored by NASA and the American Society for Engineering Education, 22 other professors from U.S. campuses spent the summer in residence. The studies and seminars provided by the participants were very well received at JPL.

Many JPL employees and activities received special awards and recognition in 1980. Among the recipients:

R. J. Parks
Goddard Astronautics Award, sponsored by the American Institute of Aeronautics and Astronautics.

R. L. Heacock
James Watt International Medal, awarded by the Institution of Mechanical Engineers in England.

D. G. Rea
Honorary doctorate of science awarded by his alma mater, the University of Manitoba.

Voyager Project
(1) Goddard Memorial Trophy, presented at the White House by President Carter on behalf of the National Space Club; (2) Honorary Group Diploma for Astronautics for 1979, awarded by the Federation Aeronautique Internationale at its 73rd General Conference in Auckland, New Zealand; (3) 1980 Engineering Project Achievement Award, sponsored by the Institute for the Advancement of Engineering.

JPL/Industry Team
Nelson P. Jackson Aerospace Award presented by the National Space Club for scientific and engineering work on Voyager.

NASA *Honor Awards*

The NASA Honor Awards program provides special recognition of outstanding individual and team efforts. The JPL honor recipients for 1980 are:

NASA Distinguished Service Medal
R. J. Parks and W. H. Bayley

NASA Exceptional Scientific Achievement Medal
D. W. Davies, A. Jacobson, T. V. Johnson, F. D. Palluconi, S. P. Parthasarathy, and F. W. Taylor.

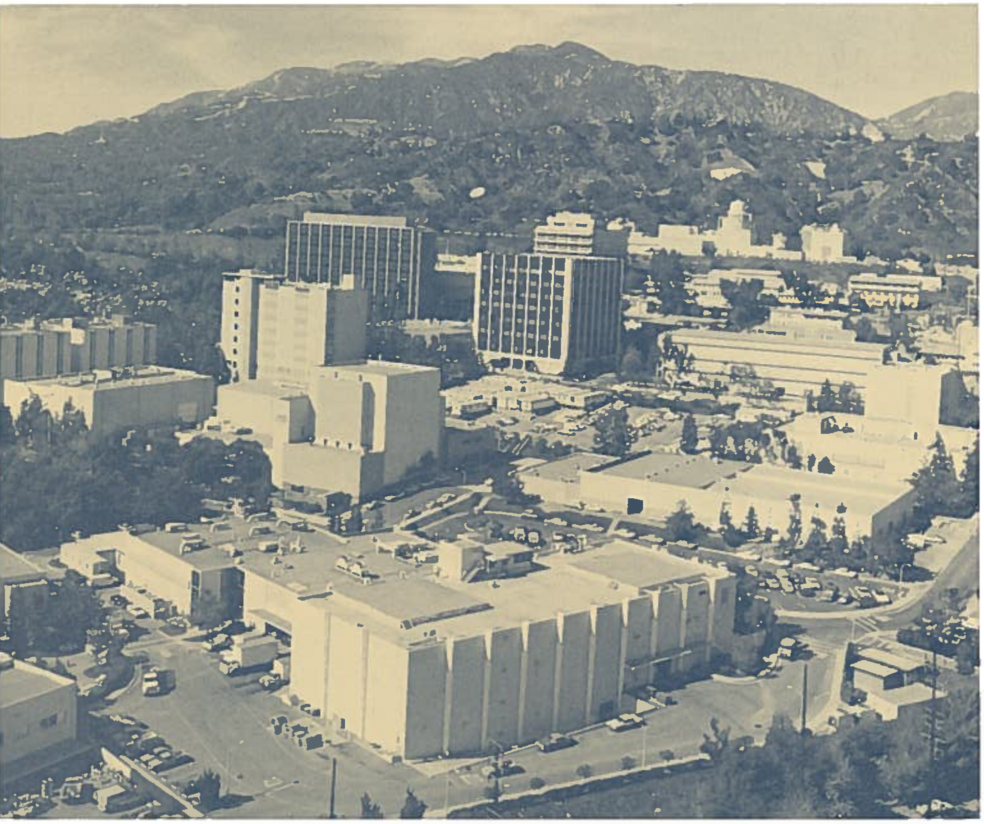
NASA Exceptional Service Medal
A. A. Avizienis, R. M. Bamford, G. H. Born, A. C. Bouck, J. P. Brenkle, N. Evans, C. E. Giffin, W. E. Kirhofer, D. B. Lame, W. E. Layman, R. B. Miller, F. T. Nicholson, H. B. Phillips, R. E. Ryan, P. J. Rygh, and C. A. Yamarone, Jr.

NASA *Group Achievement Awards*

Seasat Algorithm Development and Information Processing Team

Tidbinbilla Interferometer Development Team

Viking Continuation Mission Support Team for Pioneer-Venus:
- Multi-Probe Data Acquisition Implementation Team
- Ground Data Systems Operation Team
- Mission Navigation Team



for Pioneer-Saturn:
Deep Space Network Support Team
Mission Navigation Team
for High-Energy Astronomy Observatory C-1:
Experiment Problem Resolution Team
Gamma-Ray Spectrometer Team
Magnetic Field Satellite Project Team

Administration

Funding for JPL's ongoing and new tasks during fiscal year 1980 totalled $389,276,151, an increase of 14 percent over fiscal year 1979. Of this, $299,369,809 was for NASA programmatic tasks, $5,863,997 for NASA nonprogrammatic work, and $84,042,445 for tasks for other agencies. Energy and Technology Applications funding accounted for $66,533,272, or 17 percent of the Laboratory's total.

Procurement activities during the year increased substantially over fiscal year 1979 with total obligations up 24 percent to a new high of $222,178,000. Reflected in this increase were small business transactions of $63,705,000, an increase of 19 percent, and an increase in minority-owned business activity to $7,259,000, a gain of 15 percent. Most of the increased activity resulted from the implementation of International Solar Polar Mission subcontracts and expansion of Energy and Technology Applications programs.

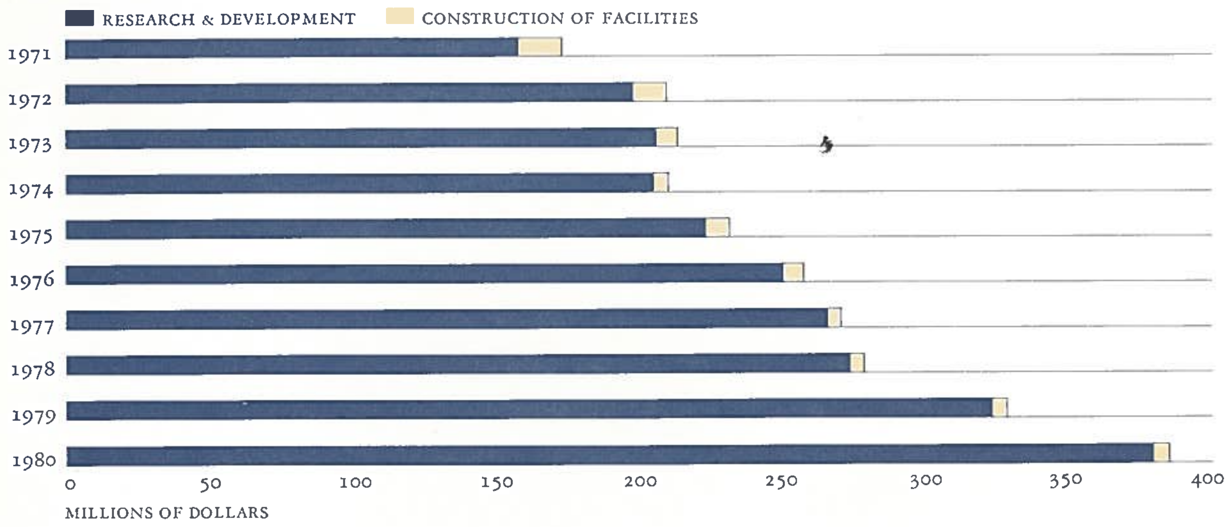
The Laboratory's work force grew by three percent during fiscal year 1980, with significant gains seen in the number of minorities and women among professional employees. Aggressive programs of employee counseling and development have helped maintain the Laboratory's exceptional staff. An upward mobility program was instituted, providing for development opportunities at various organizational levels.

The slow-scan closed-circuit TV link between the Laboratory and NASA Headquarters was operated in 1980 both for Voyager picture transmission and teleconference support. Full-color capability is scheduled for late 1981.

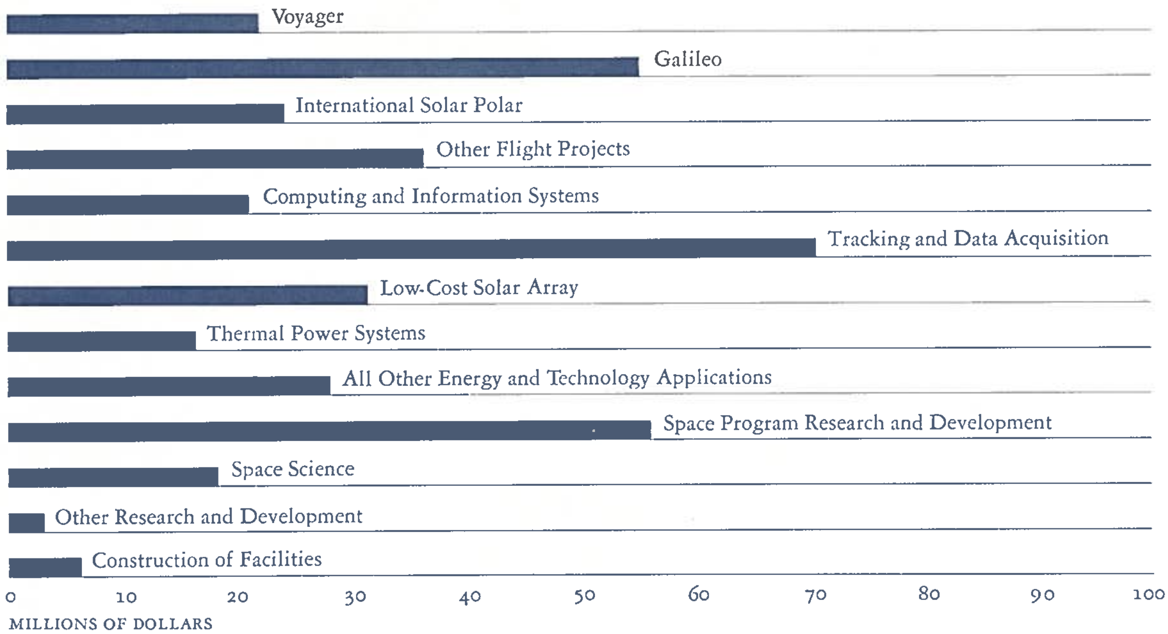
The Laboratory continued to stress energy conservation. Total energy consumption in fiscal year 1980 was 22 percent less than in fiscal year 1979 and 39 percent below the base fiscal year 1973.

Total Costs

FISCAL YEARS

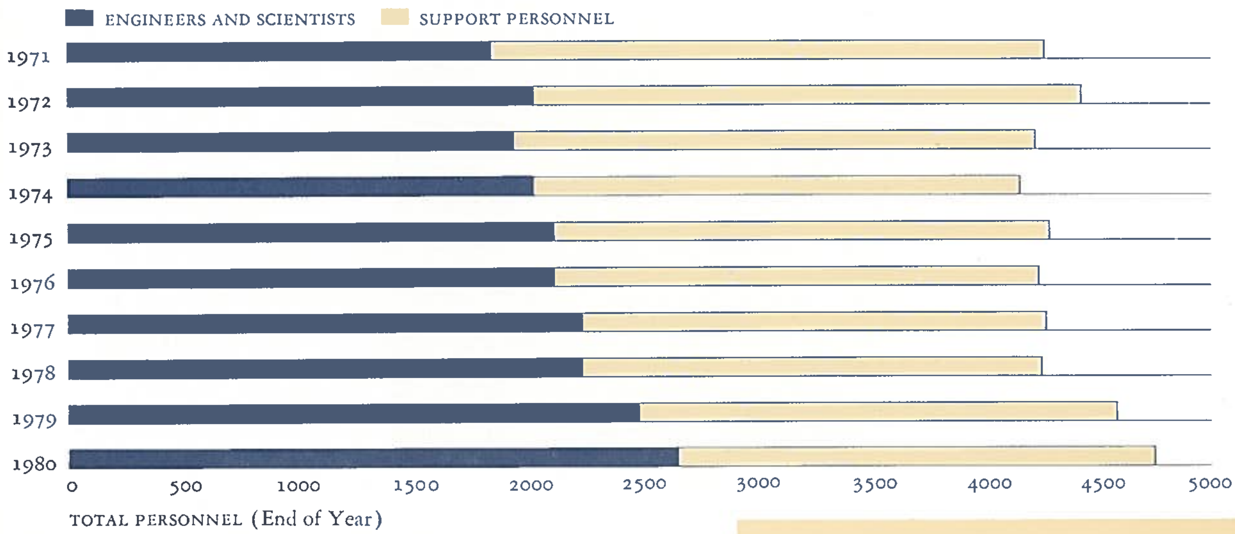


Fiscal Year 1980 Costs



Personnel

FISCAL YEARS



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