

Aeronautics and Space Report of the President

1979 Activities

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1979 Activities



**National Aeronautics and Space Administration
Washington, D.C. 20546**

Aerospace Events of 1979

In 1979 Voyager 1 and 2 sent back encounter pictures of the planet Jupiter and its moons, problems with the protective tiles on the Space Shuttle slowly yielded, insulation derived from space research protected the Alaskan pipeline, and HiMAT and the oblique wing flew research flights.

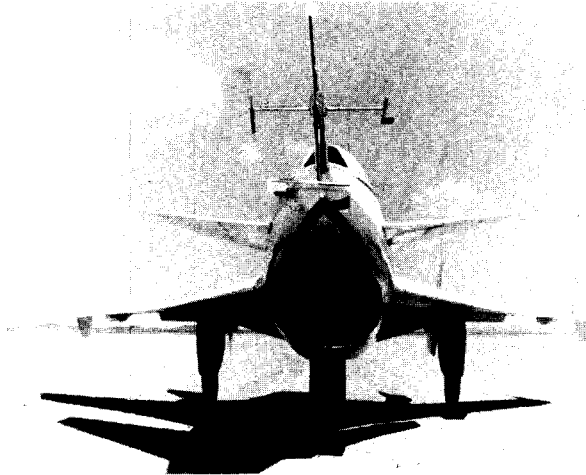
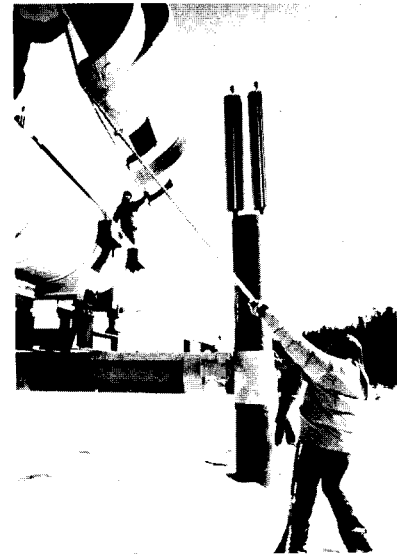


Voyager 1 flew past the planet Jupiter in March 1979. In addition to hundreds of detailed pictures of the largest planet in the solar system, the spacecraft sent back the highest resolution pictures ever taken of Jupiter's four Galilean moons. Shown here in their relative sizes: top left, Io, splotched and streaked with red, yellow, and white from magma and ash ejected by constant volcanism; top right, Europa, striated with fracture lines; bottom left, Ganymede, whose fracture lines and light and dark areas suggest crustal movement similar to Earth's tectonic plates; and, bottom right, Callisto, marked with enormous concentric rings around ancient impact craters. Io and Europa are about the size of Earth's moon; Ganymede and Callisto are larger than the planet Mercury.



At Kennedy Space Center, workmen painstakingly check the structure-to-tile contour before tiles are bonded onto the high-heat area of the Space Shuttle orbiter's body flap.

Therm-O-Trol, a metal-bonded foam insulation derived from space research, is applied along the 1300-kilometer-long Alaskan oil pipeline to retain the 82°C temperature at which crude oil will continue to flow.



The remotely piloted HiMAT (Highly Maneuverable Aircraft Technology) (left) is providing NASA and the Air Force with supersonic flight data at twice the turn capability of present fighter aircraft. The oblique wing (below) can pivot from zero to 60 degrees in flight; it may provide future high-speed transport aircraft stable, economical flight characteristics at all speeds.





Summary of United States Aeronautics and Space Activities in 1978

Introduction

In 1979 the United States programs in aeronautics and space made substantial technological and scientific progress. In aeronautics, improvements in engine components and systems promised reductions in fuel consumption, while improved computational and design techniques would provide aircraft designers with better design criteria. In space programs, the Space Shuttle moved closer to its first orbital test flight, even as Voyager spacecraft flew past Jupiter and its spectacular moons and Pioneer 11 became Earth's first spacecraft to visit Saturn and its rings. United States expendable launch vehicles attempted 16 launches; all were successful, placing a total of 18 payloads into orbit. The National Aeronautics and Space Administration (NASA) in 8 launches orbited 8 payloads, including 2 for the Department of Defense (DoD) and 3 for its own program. DoD in 8 launches orbited 10 payloads, including a new Tiros-N-series meteorological satellite built by NASA for the Department of Commerce. Among the NASA satellites launched were the third and last of the big high-energy astronomy satellites and a satellite designed to survey the Earth's magnetic field.

In Bern, Switzerland, and Vienna, Austria, the United States participated in the second and third sessions of talks with the Soviet Union on limitation of anti-satellite activity. The joint communique issued at the Vienna summit meeting stated that President Carter and President Brezhnev "agreed to continue actively searching for mutually acceptable agreement in the ongoing negotiations on anti-satellite systems."

In November the President implemented a portion of the space policy decisions announced in 1978: he designated the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce to be manager of all operational civilian remote sensing activities from space. The decision provides three paths for the nation's space-based remote sensing:

—"Integration of civilian operational activities under NOAA.

—Joint or coordinated civil/military activities where both parties' objectives can be best met through this approach.

—Separate defense activities which have no civilian counterpart." The text of this announcement is reprinted as Appendix F.

Also in November, the United Nations completed action on a proposed treaty governing activities on the moon and other celestial bodies. The text of the treaty, together with United States commentary on some of its provisos, is given in Appendix G.

In this summary chapter, highlights of 1979 in the national aeronautics and space programs are organized topically across the government rather than by agencies responsible for particular activities. Subsequent chapters further describe the activities of the agencies with the largest programs in aeronautics and space.

Communications

Communication satellites are among the most profitable space systems to result from the nation's investment in space activity.

Operational Space Systems

Intelsat. The internationally owned INTELSAT global communication satellite system now consists of three active Intelsat IV-A satellites in the Atlantic Ocean region and two in the Indian Ocean region. The Pacific Ocean region is served by spacecraft from the Intelsat IV series. Development of a follow-on generation, the Intelsat V, progressed, with launch of the first flight model projected for mid-1980. Intelsat V will operate in both the 6–4 gigahertz (GHz) and 11–14 GHz bands along with the added flexibility of a "cross-strap" mode of operation (signal sent up to satellite on 6 GHz and returned down from satellite on 11 GHz; and up on 14 GHz and down on 4 GHz). Of the eight Intelsat V satellites under procurement, four will provide maritime services. Those four satellites can be launched by any one of three vehicles: the Atlas-

Centaur, the NASA Space Shuttle, and the European Space Agency's Ariane.

Domestic Commercial Communication Satellites. Westar 3, launched in September, brought the total number of domestic communication satellites to 8. These operate in the 4 and 6 GHz bands. Two are part of RCA Americom's SATCOM system, 3 are in Western Union Telegraph's WESTAR system, and 3 are in AT&T's COMSTAR system. These satellites provide message toll service, television distribution, and single channel per carrier or multiple channels per carrier for transmission of voice, data, television, and digital data. In July 1979, the three-year ban on commercial usage of the AT&T COMSTAR system expired. Satellite Business Systems (SBS) continued its development efforts toward a two-satellite system. It plans to use the 12 and 14 GHz bands and 5- and 7-meter Earth stations to provide voice, data, and television transmission services to large industrial and government users. The matter of construction of the SBS satellite system is still before the U.S. Court of Appeals for the District of Columbia. Applications have been received from Western Union Space Communications, Inc. (SPACECOM) for an advanced Westar using both the 4-6 and 12-13 GHz bands. In December 1979, applications were received to launch the third and fourth Satcom satellites, and the third SBS satellite.

Previous decisions by the Federal Communications Commission (FCC), authorizing more flexibility in the design of receive-only Earth stations for cable television and other types of television and audio distribution systems, have led to the authorization of over 1800 receive-only Earth stations for the distribution of these services. The Corporation for Public Broadcasting (CPB) and National Public Radio (NPR) have begun to construct their Earth stations as part of the satellite distribution of multiple audio programming to NPR radio stations and are looking toward an operational date early in 1980. Several applications for authorization of new systems have been received, including those from the Mutual Broadcasting Company's audio distribution network, the Appalachian Regional Commission's television distribution system, and from both the Associated Press and the United Press International wanting to establish their own satellite distribution networks. The FCC has also received a proposal by the Western Union Telegraph Company to make available transponder capacity in the WESTAR satellite system for television transmission solely within Mexico.

Late in January 1979, the FCC released a Notice of Inquiry designed to explore legal, technical, and policy questions associated with the possible deregulation

of Earth stations. The number of all Earth stations that have been authorized to date is in excess of 2300.

Military Communications Satellites. Three broad categories of space communications are identified for the defense establishment:

- worldwide point-to-point communications for fixed users with high capacity and high data rate
- communications for mobile users, with moderate capacity and low data rate
- command and control of strategic nuclear forces.

DoD progressed in all three categories in 1979 with (1) the successful launch of Defense Satellite Communications System (DSCS) II satellites 13 and 14, (2) the successful launch of the second Fleet Satellite Communications (FLTSATCOM) satellite, and (3) the achievement in May of the initial operating capability of the Air Force Satellite Communications system (AFSATCOM). The FCC is reviewing an application filed by Hughes Communication Services, Inc., to construct a satellite system known as LEASAT which will replace the existing Fleet Satellite Communications (FLTSATCOM), providing the Navy and other military services with a nearly global communications capacity. The LEASAT system is scheduled to begin operation in October 1981.

Marisat. Commercial satellite service to shipping continued to develop and expand. Service is currently provided through Marisat in the Atlantic, Pacific, and Indian oceans to approximately 300 ships. Eventually up to 8000 ships are expected to be fitted for satellite communications.

On February 15, 1979, the United States, pursuant to the International Maritime Satellite Communications Act of 1978, signed the convention on the International Maritime Satellite Organization (INMARSAT) in London. INMARSAT will provide global telecommunications services for maritime commercial and safety purposes. Since 1972, the United States has been working with other countries to improve maritime communications through a global satellite communications system that meets the requirements of merchant fleets. The new organization, which will be headquartered in London, came into existence on July 16, 1979, when the required number of investment shares had been taken up by signatories. Patterned closely after INTELSAT (the International Telecommunications Satellite Organization), INMARSAT is expected to begin operations in the early 1980s, relying primarily on Intelsat V spacecraft, equipped with maritime communications payloads, for its first generation of satellites.

Military Navigation Satellites. The new military navigation satellite system is the NAVSTAR Global Positioning System. It is a joint-service system to provide high-accuracy, global position fixing in three dimensions. Field testing of the NAVSTAR Global Positioning System user equipments with the four GPS satellites launched in 1978 demonstrated the required accuracies, and the program began full-scale engineering development in August.

Space Communication Experiments

Experimental Satellites. Satellite experiments associated with the United States-Canadian Communication Technology Satellite (CTS) in the 11.7–12.2 GHz band began winding down in 1979 after three years of operation. With notification of termination at mid-year, most American experimenters are completing their projects. In some of the experiments dealing with program delivery, experimenters are making plans to use proposed or existing domestic satellites in the 6–4 GHz bands to continue operation. Similar projects are being completed in the 2.2–2.69 GHz band associated with the Application Technology Satellite (ATS 6) which was terminated in the last quarter of 1979.

Emergency and operational communication provided through the operation of ATS 1 and ATS 3 has grown somewhat. These satellites have narrow-band VHF transponders and are basically being used by experimenters to send narrow-band voice and data communications to 37 fixed and portable receiving stations. Messages deal with medical emergency, state government operations, and church administration. Two new areas of VHF satellite operations have begun this year; one experiment uses satellite data telemetry to control the flow of natural gas in cross-country pipe lines; another experiment assesses the role of satellite communications in search and rescue operations in remote areas of the United States.

Communications Research. NASA identified the two areas in satellite communications that need improvement. They are (a) multiplying the use of existing frequencies and (b) extending the usable frequency spectrum. The multiplication of frequency use depends on the development of spaceborne multibeam antennas; several frequency ranges and a 15-beam antenna began range testing. The second problem was being examined in a prototype system that could greatly reduce the bandwidth used by digitized television signals.

DoD was also researching means of using higher frequency bands, partly to avoid the congestion in the lower frequencies and partly to lessen the effect of jamming. In 1979 new components were developed that could operate in the EHF frequency

range. A developmental test model of a laser communication device was completed and testing was begun. Laser communications would allow transmission of high data rates and protection against jamming.

Communications Negotiation. The year 1979 was an active one for the United States in international deliberations on space communications.

WORLD ADMINISTRATIVE RADIO CONFERENCE. Once every 20 years the International Telecommunications Union convenes a General World Administrative Radio Conference to review and adjust the world-wide allocation of radio frequencies. Since the United States is a major communications user and since this was the first such conference in which international space activities were a major consideration, substantial effort went into preparation for and participation in the conference. This conference met for ten weeks, addressing the many issues of frequency allocation with an intensity that reflected the rapidly growing pressure on the existing frequency spectrum. At the conclusion of the conference, the United States delegation reported general satisfaction with the results; some 95 percent of the United States positions had been accepted.

DIRECT BROADCAST SATELLITES. The United Nations, in the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space, made progress on elaborating principles for use of artificial Earth satellites for direct television broadcasting. Only two issues appear to be blocking consensus—the principles on consultation and on agreement between countries. Both involve the concept of prior consent.

Much of the background on this subject dates to 1977, when a World Administrative Radio Conference was held under the auspices of the International Telecommunications Union (ITU). The conference adopted a plan of national assignments of frequencies and orbital slots for direct television satellite broadcasting for Regions 1 and 3, which comprise the world's surface except for North and South America (Region 2). The same conference also treated the problem of "spillover." Broadcast satellites transmit a wide beam. Although the beam can be shaped somewhat by the antennas aboard the satellite, it is impossible to shape the beam to conform with national boundaries. Hence there is inevitably spillover of the beam into neighboring countries. The 1977 conference established limits, based on technological realities, on this unavoidable spillover, seeking to reduce it to a minimum.

Although ITU's technical regulations impose in effect a prior consent régime for direct broadcast satellites in Regions 1 and 3, in the United Nations discussions the Soviet Union and the Eastern-bloc countries insist that there ought to be United Nations principles for direct broadcast satellites which

establish politically a requirement that direct broadcast signals cannot cross national borders without the prior consent and agreement of the neighboring country.

A large group of delegations would exclude the requirement for prior consent in the case of unintentional spillover but would apply it to the case where a country intends to broadcast its signal into some country other than its own.

The United States and a very small number of other delegations view the present language of the proposed principle on consultation and agreement between countries as limiting and as eroding the principle of free flow of information, a fundamental human right recognized in such international instruments as the Universal Declaration of Human Rights in Article 19 of the United Nations Charter, which declares the right of people "to seek, receive, and impart information and ideas through any media and regardless of frontiers"; this has been reaffirmed in Resolution 33/115 of the General Assembly and most recently in the UNESCO Declaration on the Mass Media. The United States fully supports a principle providing for full consultations prior to the establishment of any international direct broadcast satellite by a country—consultations which could include the subject of program content—but not that they must end with an explicit agreement or the prior consent of a receiving station before such broadcasting may begin.

The issue obviously is ideological and political and may be difficult to resolve. It remains to be seen whether consensus will ever be reached.

Earth's Resources

The remote sensing of Earth's surface and atmosphere from spacecraft and aircraft continued in 1979. Some of these sensing systems were tentative and experimental, others were semi-operational, and a few were fully operational.

Inventorying and Monitoring

Earth Resources. The most significant activity in land observations was in agriculture. Analysis of data from the three-year Large Area Crop Inventory Experiment (LACIE), an experimental use of remotely sensed data for crop measurement and prediction, had shown that it is possible to distinguish wheat from similar crops and to obtain reliable yield estimates.

To build on the LACIE experience, AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing) officially began on October 1, 1979. AgRISTARS is a 6-year

program of research, development, evaluation, and application of aerospace remote sensing for agriculture and renewable resources. It is a cooperative effort of the Departments of Agriculture, Commerce, and Interior; NASA; and the Agency for International Development. The goal of the AgRISTARS program is to determine the usefulness, cost, and extent to which aerospace remote sensing data can be integrated into existing or future agricultural measurement systems to improve the objectivity, reliability, timeliness, and adequacy of data for resource management as well as commodity production information.

All participating agencies are closely linked in a joint program. Within AgRISTARS USDA has the responsibility for defining the overall information requirements, performing research related to development of yield models and their applications, development of an agronomic data base and collection of ground data, and evaluation of technology for its utility and affordability. NASA is responsible for research, development, and testing for foreign crop-area estimation, Landsat data acquisition, and spectral inputs to various research activities. NOAA of the Department of Commerce provides the meteorological data that supports research work on yield models. The Department of the Interior is charged with Landsat data storage, retrieval, and dissemination. The Agency for International Development will evaluate the utility of research, development, and testing results for application in developing countries.

Landsat data, combined with extensive ground-gathered data, improved the official 1978 year-end estimates of Iowa's planted corn and sorghum acreages. This was the first time that researchers of the Department of Agriculture had analyzed data from Landsat for an entire state for regularly scheduled reports of crop acreage. The satellite data helped reduce sampling errors and demonstrated that Landsat data can be used to improve crop acreage estimates at the state and sub-state level. However, resource efficiencies and timely acquisition of Landsat data must be achieved before this approach can be used in operating programs. A vital part of the statistical estimation procedure is development of sampling frames; remotely sensed data are particularly useful for the development of improved frames. Satellite imagery is now being used as a basic source for establishing homogeneous strata and for providing a basis for the digitizing of entire frames to improve area measurement accuracy. Initial activity is now under way with AID to provide sampling frame procedures and techniques to cooperating host countries at their request and to extend the use of satellite imagery to get better

land-use stratification within individual states of the United States.

During 1979 USDA employees assigned to an AID project completed a schematic soil survey of Saudi Arabia using Landsat imagery. Under a cooperative agreement with the Treasury Department, a schematic soils map was prepared for publication on a Landsat mosaic. On the domestic scene Landsat digital data were used as an aid in the National Cooperative Soil Survey. The Department continued its cooperative effort with NASA under the nationwide Forestry Application Program to identify and investigate new remote sensing methods, with special emphasis in the application of inventory procedures for renewable resources and to application of remote sensing technology to the management of forest and range lands. Specific project areas included detection, classification, and measurement of disturbances, including forest, insect, and disease damage; classification and mensuration of forest and range land resources; regional and large area renewable resource inventories including timber management surveys; environmental monitoring and the land management planning process; and vegetation classification with topographic data.

International interest in Landsat data continued to mount. With the coming into operation of the Landsat station in India in August, the total of foreign Landsat stations rose to 7; 3 more were under way, and discussions were in progress on 2 more. In addition to foreign Landsat stations, foreign requests for Landsat coverage grew rapidly.

Requests for coverage from United States users also grew. Other uses included U.S. Coast Guard, NOAA, and USGS monitoring of the oil spill off the Yucatan coast. Beginning in June, NASA provided Landsat coverage of the Gulf of Mexico to these agencies and to the Mexican government; it delineated the spread and movement of the huge oil slick.

The development of geobased information systems continued to grow in popularity. In these, Landsat data are put in a computer along with terrain data and soil map data; as subsequent Landsat data reveals changes in land use the data bank can be used to predict problem areas for drainage and erosion, pinpointing the needed field inspections. Success with experiments of this type led the Iowa legislature to appropriate funds for purchase of a state-owned system for Landsat applications; Florida is planning to develop a statewide Landsat-based information system.

In forestry, the California Department of Forestry chose Landsat technology over other methods to meet a requirement by the legislature for a statewide inventory of forest lands by August 1, 1979, with updates to follow at five-year intervals.

In control of water resources, Landsat data were used in a demonstration project in Florida to define the land cover in the basin of the Apalachicola River to better predict the effects of existing and planned agricultural and industrial developments. Along the Gulf of Mexico, Landsat data are being used to study Choctawhatchee Bay for the effect of urban development on water shortages in the Ft. Walton area.

In longer term development of methods for using remotely sensed information in prospecting for mineral deposits, NASA has been working closely with university and industry scientists to evaluate the usefulness of satellite data in geological reconnaissance. At 12 test sites with known deposits of copper, uranium, or petroleum Landsat data were examined for broad area possibilities and aircraft flew more detailed sensing missions over the most promising locations. At Copper Mountain, Utah, a multispectral scanner in an aircraft detected patterns of iron oxide stains over known uranium deposits. When a similar pattern was detected nearby in supposedly barren land, a ground check by geologists was conducted and the company owning the mineral rights staked a claim.

A new tool in geologic assessment was put into operation in 1979 with the launch of Magsat in October. The first satellite designed to survey the Earth's vector magnetic field and orbiting at a much lower altitude than previous satellites measuring the magnetic field, Magsat is intended to return much more detailed information about the magnetic anomalies within the Earth's crust, thus defining crustal structure in large-scale models for mineral assessment in remote areas.

At the United Nations, work on principles to govern remote sensing of the Earth's natural resources and environment continued into its fourth year. The United States does not see the slow pace of negotiations as a basis of pessimism. Growing experience with Landsat programs is educating all nations to the potential and possible modes of operation for remote sensing systems.

Access to and the dissemination of remote sensing data or information derived therefrom still raises a diversity of views despite extensive discussion over the last four or five years. In very early discussions, the right of a nation to sense the territory of another nation without the latter's prior consent was questioned. With more and more nations having this capability and recognizing the potential value of this space application, this argument has largely disappeared and in its stead many delegations now seek to impose prior consent on the dissemination of data or information. Other delegations, including the United States, support the right

of a nation operating a sensor or of a nation with a receiving ground station to disseminate remote sensing data openly without the prior consent of the observed nation. The Soviet Union has proposed that data having a resolution of no better than 50 meters be openly disseminated while data better than 50 meters resolution be subject to the prior consent of the observed nation.

The United States believes that Landsat-type systems can continue to provide significant national, regional, and international benefits that far exceed the slight risk of injury to the economic, political, or national security of any country.

If the principle of prior consent were adopted, the international cooperative program under which the Landsat ground stations have been located abroad would have to be ended since data are held not only by the country controlling the spacecraft but also by the ground-receiving-station countries. In response to the Soviet proposal, the United States and other delegations pointed out that from a technical standpoint spatial resolution was not a reliable or standard reference, a conclusion supported by the Scientific and Technical Subcommittee as well as by COSPAR (the Committee on Space Research of the International Council of Scientific Unions).

Another arena of Earth observation has been the study of the dynamic processes within the Earth through the measurement of tectonic plate movement and the resulting deformations and shifts of the crustal surface. NASA has for four years used satellite ranging systems along the San Andreas Fault in California and has measured slippage between the Pacific and North American plates of from 6 to 12 centimeters per year. A fourth data phase was completed early in 1979 and the data are now being analyzed.

Mobile lasers have been installed at four stations and a second-generation laser installed on a truck by the University of Texas will take measurements from 25 sites in the western United States. Other mobile and fixed lasers are operating overseas in a number of countries in an international network. United States participation, in addition to NASA, involves the National Science Foundation (NSF), National Geodetic Survey, USGS, and the Defense Mapping Agency.

Monitoring the Sea State. The 99-day operational phase, followed by the abrupt premature failure, of NASA's Seasat 1 satellite in 1978 was pursued in 1979 by extensive evaluation of the quality and validity of data from Seasat and from Nimbus satellites that had employed oceanographic sensors. NOAA convened a workshop on the usefulness of Seasat data in measuring the high winds, waves, and

heavy precipitation from storms at sea. The conclusion was that imaging radars on satellites are very effective in both atmospheric and ocean-surface measurements. In the ability of satellite instruments to measure waveheight and mean sea level, NOAA compared satellite data with surface-truth data and found agreement for waves with heights up to 30 centimeters.

In March NOAA, NASA, and DoD completed a study on possible development of a National Oceanic Satellite System. The joint study explored the operational needs for oceanographic information in civil and defense agencies and the technical requirements in the space and ground segments of such a system.

NOAA continued monitoring with its Goes spacecraft the position, warm and cold eddies, and thermal boundaries of the Gulf Stream. These data, published in weekly maps, are used by fishermen to locate productive fishing grounds. In 1979, for the first time NOAA began issuing surface temperature maps of the waters adjacent to Alaska; these should be of use to fishermen and researchers in correlating fish catches to temperature factors. All 22 of NOAA's data buoys located in waters around the world were converted to transmit environmental and communications data through the Goes satellites.

Environmental Analysis and Protection

One of the early successes of the United States space program was the weather satellite. For more than a decade complex systems of weather satellites have been operational in weather forecasting. In the last few years, research has started on the less-discernible trends of world climate and changes in Earth's upper environment caused by man-generated pollutants.

Weather Satellite Operations. During 1979 NOAA operated a two-satellite polar-orbiting weather satellite system. During the first half of the year the former Improved Tiros Operational Satellite (ITOS) system was being replaced by the new Tiros-N system. In October 1978 NASA's experimental prototype, Tiros-N, had been launched and replaced one of the two ITOS satellites in the operational network. On June 27, 1979, NOAA's first satellite in the new series, NOAA 6, was orbited and in a few weeks it replaced NOAA 5, completing the new network.

The Tiros-N satellites are in near-polar, Sun-synchronous orbits, crossing the equator some 12 hours apart. Each satellite has four primary sensors: a very-high-resolution radiometer, a vertical sounder comprised of three complementary sounding instruments, a data collection and location system, and a space environment monitor. With improved visual

and infrared imagery, they will also measure temperature and moisture and at stratospheric levels will monitor proton and electron flux. A new ground system was accepted in February 1979 to handle the extremely large volume of digital data generated by the Tiros-N system.

NOAA's other system of satellites is the Geostationary Operational Environmental Satellites (GOES). In 1979 this system supported the international Global Weather Experiment and the operational utility of GOES imagery was improved in March 1979 by the introduction of a new interactive computer system which provides better accuracy and faster response time in gridding of GOES images.

DoD's weather satellite systems is the Defense Meteorological Satellite Program, supporting military operations with high-quality visual and infrared imagery and other specialized weather data; it also furnishes NOAA with data supplementary to its satellite systems. From polar orbit DoD's two weather satellites acquire data on the world's weather four times each day, store it, and later transmit it to the Air Force and Navy weather centers in Nebraska and California respectively. The data are also transmitted in real time to mobile readout stations in key locations around the world to support tactical operations. In 1979 the fourth Block 5D satellite was launched and became operational in July. In addition to providing cloud imagery, this satellite has a new microwave sensor that takes a vertical temperature profile as well as several special sensors that read ionospheric data into forecasts of ionospheric electron counts. Design was completed and a contract awarded for a passive microwave imager to measure precipitation, cloud and liquid water content of the atmosphere, ocean surface wind, and sea ice distribution.

Weather Research. In December 1978 the World Meteorological Organization opened its long-awaited Global Atmospheric Research Program (GARP). The first phase was a year-long Global Weather Experiment. Several United States agencies are involved, with a special role for NOAA and NASA environmental satellites. In conjunction with weather satellites from other nations and extensive ground-truth data collection, they should provide a high-density data bank; systems and instruments also will benefit from intercalibration. NOAA began comparing its satellite data with those from Japanese and European Space Agency satellites and found the data to be quite compatible. Comparison periods will be continued indefinitely at the rate of twice a year.

One of NOAA's case studies involved a Tiros-N orbit across the United States on May 2, 1979, 12 hours before tornadoes struck along the border of Oklahoma and Kansas. The study revealed the

presence of a low-pressure area, an intense moisture front with convectively unstable air, and strong divergence of the upper-level jet over the area. Tiros-N had indeed flagged the precursor conditions of development of severe storms and made advance warning possible.

The improved radiometer on Tiros-N and the Earth Radiation Budget experiment on Nimbus 7 enabled more comprehensive study in 1979 of the Earth's radiation budget. Not only is the radiation budget important for meteorological forecasting, it is also of interest to students of fluctuations in climate. Data from eight narrow-field-of-view channels are being used to develop computer programs for angular models, which will improve accuracy of readings of radiation outgoing from Earth.

Atmospheric and Magnetospheric Research. For some years several Federal agencies have been making space-based, air-based, and ground-based measurements of constituent gases and particles in the various layers of the Earth's outer environment. The range of interests has grown from concern over charged-particle effects on radio communications, to the pass-through effects on weather, to effects of man-made pollution on the ozone layer, to the effect on Earth's climate, and most recently to charged-particle effects on electric charging of geosynchronous spacecraft.

NOAA continued research on several aspects of atmospheric clouds and moisture content. Evaluation continued of microwave-derived temperature, water-vapor, and thermal wind measurements made by NASA's Nimbus 6 satellite with its Scanning Microwave Spectrometer. The satellite soundings proved to be as good or better than ground-based soundings down to the 700-millibar pressure level over water and down to 500 millibars over land. Other studies of microwave data sought to improve the accuracy of temperature measurements by correcting errors induced by heavy precipitation.

In research into hurricanes and convective cloud systems, NOAA continued to use satellite-derived data and to compare it with aircraft-derived data. In 1979 this technique was used to study Hurricanes David and Frederic as these storms moved up the Caribbean to their landfalls in Hispaniola, Cuba, and then the United States. The satellite and aircraft data may provide information on the degree to which cloud motion represents wind speed and direction at the lower levels, and the accuracy of satellite estimates of storm intensity.

Several approaches were taken to extend and improve the data base for forecasting of weather over the northern Pacific Ocean, where Alaska's weather originates. Since numerical forecasting over oceans has serious limitations, NOAA performed operational tests on a new technique using satellite data

to locate and track developing systems in the mid-Pacific through estimates of central pressure. Data from geostationary satellites were used to determine low-level cloud movements over the Pacific; this is in addition to previous use of such data for high-level winds in global forecast models. The Pacific weather data base was extended even farther west in 1979 by regular acquisition of cloud images over the western Pacific from Japan's geostationary meteorological satellite; this area is beyond the range of United States geostationary satellites.

During 1979 the Environmental Protection Agency (EPA) worked with NASA to use the high technology developed for space exploration to address the problems of pollution. EPA and NASA have entered into a joint research program to improve the usefulness of satellite imagery for studying the dynamics of large-scale pollution episodes. The development and movement of such episodes were first identified through visibility isopleths derived from routine National Weather Service visibility distance measurements. Areas with low visibility show up on satellite images as hazy areas which can be differentiated from clouds. Occurring in the summer and early fall in the eastern United States, these low visibility episodes have been increasing in severity and geographic extent over the last 20 years. The reduction in visibility has been associated statistically with high concentrations of sulfate particles and other pollutants; together these may affect both health and ecology.

The dimensions of hazy air masses are on the order of hundreds of kilometers, with travel distances of thousands of kilometers. Because of the large dimensions, satellite observations offer an excellent means for observation of their formation, extent, travel, and dissipation. This information, which can be obtained from existing satellite imagery, will be used to determine meteorological conditions associated with the haze masses so that their formation and movement may be predicted. Also the data will enable us to associate periods of intense pollution with health effects.

A second EPA-NASA joint effort is the remote sensing of accelerated energy-fuel development and the associated environmental impacts. In anticipation of increased energy requirements of the next quarter century, the Federal government is promoting the development of untapped national energy resources such as low-sulfur coal reserves, oil shale, and geothermal resources, all of which are located in abundance in the western United States. Their development will usually involve greatly increased strip mining, along with the construction of large conventional power and coal gasification plants in presently pristine areas of the West. EPA and NASA are obtaining essential baseline and trend data by

remote sensing. As part of this effort, the hardware and software needed for processing remotely sensed digital data were transferred to EPA. The EPA Data and Analysis System can handle data from EPA's present remote sensing systems and from currently available and proposed satellite multispectral scanner systems.

The EPA-NASA remote sensing capability has been used for such purposes as showing the impact of land use activities on water quality in Apalachicola Bay, Florida; assessing the damage to hardwood trees from sulfur dioxide emissions; and measuring turbidity and sediment concentrations in water bodies. All results evaluated thus far are very encouraging. They demonstrate the feasibility of using satellite and aircraft-acquired multispectral scanner data for monitoring the effects of energy resources development.

The next step in expanding the EPA's remote sensing is the development of a Geo-Referenced Interactive Data Base System (GRIDS). This system would handle various types of digitized environmental data and provide graphical displays of the overlaid data sets, producing, in effect, an analog model of the geographical environment under study. The environmental analog becomes dynamic when data sets from different periods are compared. Further steps in developing this system would incorporate various models (e.g., air and water quality), thereby permitting a graphical and dynamic presentation of the impact from an undesirable environmental action.

A third EPA-NASA cooperative effort is the development of better instrumentation for measurement of airborne sulfur dioxide. During the past year, a mobile ground-based ultraviolet (UV) lidar system was developed for measurement of sulfur dioxide and aerosols in stack plumes. This system consists of a unique laser, developed at NASA's Langley Research Center, which produces two independently tunable UV wavelengths that are separated in time by 100 microseconds. The laser is combined with a dual-channel receiver for simultaneous detection of the backscattered light in the UV and visible portions of the spectrum. The mobile UV lidar system was demonstrated in a joint field experiment conducted in cooperation with the Maryland Power Plant Siting Program and EPA at the Morgantown generating plant of the Potomac Electric Power Company.

The lidar system used two UV wavelengths near 300 nanometers in the measurement of sulfur dioxide concentrations in the power plant plume and the 532-nanometer wavelength of the pump laser for measurement of particulate distribution in the plume. In addition to the lidar system, several other instruments obtained corroborating and supporting

data, both in the stack and in the plume. UV lidar measurements were made both day and night. In-stack measurements compare well with the lidar-determined concentrations of sulfur dioxide. The results indicate that a UV lidar system can measure the extent and average sulfur dioxide concentration in power plant plumes. With increased power, a UV lidar in an aircraft can measure sulfur dioxide at long ranges downwind of the stack to near-ambient concentration levels. Development is nearly complete of an airborne UV lidar system to measure sulfur dioxide, ozone, and aerosols. The system was flown to measure ozone and sulfur dioxide in the fall of 1979.

A fourth application of space expertise to pollution problems is the validation of plume models. Verification studies of plume rise and dispersion models, using the lidar data base from a previous lidar plume dispersion experiment, were completed in 1979. Comparisons were made between measured and predicted values for the standard deviation of the particulate distribution in the plume in the vertical and the cross-wind direction. The lidar system has been demonstrated to be effective in obtaining plume dispersion parameters that cannot be measured with passive techniques.

The study of climate was officially mandated in the National Climate Program Act of 1977. This led to the establishment of NOAA's National Climate Program Office, engaged in the long term and spatially extended collection and analysis of all the environmental variables studied in connection with the weather and the oceans. In 1979 NASA supported the NOAA program with studies and measurements of aerosols in the atmosphere. With the launch of the SAGE (Stratospheric Aerosol and Gas Experiment) payload, NASA was well situated to gather remotely sensed data on the violent eruptions of the volcano La Soufriere in the Caribbean in April. Combinations of airborne instrument readings and SAGE data agreed that heavy concentrations of aerosols rose to and traveled at the 18-kilometer altitude. This was the first time a remote sensing capability was in place to measure such a phenomenon quantitatively and to map the spread of the aerosols around the globe. These data will also suggest how pollutants might be transported around the world, with implications for the siting of industrial complexes that exhaust large quantities of airborne wastes.

A phenomenon in the magnetosphere that has been of concern to both the military and civil sides of the national space program has been spacecraft charging—the buildup of excessive electrical charges on spacecraft in geosynchronous orbit, posing a threat to spacecraft electronics. DoD has taken the lead in research on this problem. In 1979 theoretical

studies were supplemented with the launch of the Scatha payload—some 12 experiments designed to measure, analyze, and define the amounts and causes of the charging. Data from the Scatha satellite combined with other data from theoretical and empirical studies are being made available in a handbook and updated models.

An experimental radar, designed to provide new knowledge of winds, turbulence, and waves in the atmosphere between about one and 100 kilometers, is being constructed in Fairbanks, Alaska. The radar transmits a 50-megahertz signal at a peak power of 6.4 megawatts from a phased dipole array of 40,000 square meters.

The device measures the downward scattered radiation arising from variations in the radio refractive index; at the highest elevations, the returned scattered radiation arises from free electrons. The scattered radiation, when suitably processed, can be used to infer air motions along the local vertical, and this can be done about every four minutes. Conventional balloon techniques, by contrast, permit such measurements only twice a day, rockets even less frequently. Thus the motion of the atmosphere can be measured in much greater detail. Such information is vital for an understanding of weather systems, atmospheric composition and chemistry, radio propagation, and atmospheric wave motions. The facility is being constructed by scientists from NOAA's Aeronomy Laboratory in Boulder, Colorado, with support from NSF.

Although the near-Earth magnetic field has a simple dipole character, its more distant structure is severely distorted by interaction with hot solar plasma (ionized gas) that continuously blows out from the Sun. The outer reaches of the Earth's magnetic field cause a "magnetospheric" cavity in this "solar wind" some tens of Earth radii across and stretching away from the Sun past the distance of the moon's orbit.

An important cause is the motion, in the high-latitude ionosphere, of magnetic field lines that trace to great distances into the magnetosphere. Plasma tracing these trajectories can move at speeds of kilometers per second, corresponding to driving electric fields tens of kilovolts across the dawn-dusk ionospheric polar cap. A qualitatively new capability is now available to measure plasma velocities (and derived electric fields) continuously over the entire band from 60° to 75° magnetic latitude. With support of the NSF a 50-meter-diameter fully steerable antenna has been added to the Millstone Hill radar at Westford, Massachusetts. Data collected to date with this newly upgraded facility are already extending the understanding of both solar control and atmospheric effects of these circulation patterns. Magnetically quiet days have been found to have a

plasma flow pattern consistent with expectations from present idealized models, while increasingly disturbed days show subtle to dramatic departures from this pattern.

At the Smithsonian Astrophysical Observatory, analysis of the 1976 gravitational redshift experiment, in which an extremely precise hydrogen maser clock sent into space was compared with an identical clock on the ground, was completed in 1979. A recalculation of all systematic errors and the formal statistical errors has led to a final result: the relationship between the observed redshift and the prediction from the equivalence principle is verified to within 143 parts per million.

A second test of the equivalence principle with clocks involved comparison of hydrogen-maser and superconducting-cavity clocks at Stanford University to search for a possible nonmetric behavior of gravitation. Evidence for this behavior would be that the frequency difference between clocks operating on different physical principles would be affected by changes in the Sun's gravity potential owing to the laboratory's motion during the period of measurement. No effect was seen at the 1 percent level of sensitivity.

During 1979, a hydrogen maser was successfully operated at a temperature of 25 K, made possible by a new type of gaseous wall coating material frozen in place. The stability available from the new cold maser is at the 10^{-17} level and work is in progress to demonstrate this tenfold improvement over present technology.

Space Science

Space science can be considered to begin in the region of interactions between the Earth's magnetic field and the incoming solar wind. Beyond that, it encompasses the solar system and the entire detectable Universe.

Sun-Earth Studies

Much remains to be learned about the Sun, the sole source of Earth's light, life, and energy; and about the interactions between solar emissions and the layers of Earth's environmental shell.

The Sun. In 1979 the International Sun-Earth Explorer (ISEE) satellites marked their first full year of operation as a complete three-satellite system. This system, a collaboration between NASA and the European Space Agency (ESA), has two satellites (ISEE 1 and 2) traveling in highly elliptical orbits in and out of the Earth's magnetic field, reporting on a cross section of the Earth's magnetosphere; the third ISEE satellite, launched late

in 1978, is positioned farther out (some 1.6-million kilometers from Earth) at the Sun-Earth libration point. As a sentinel between Sun and Earth, it reports on events in the solar wind about one hour before these same effects reach the Earth's magnetosphere. Over a period of time, the flow of data from this triangle of satellites will tell us much about the fluctuations of the magnetosphere in response to the aberrations in the solar wind, in addition to giving reliable short-term warning of imminent disturbances in the magnetosphere and ionosphere.

With the approach of the point in the Sun's 11-year cycle known as the "solar maximum"—featuring maximum activity on the solar surface—the international scientific community has joined together in an International Solar Maximum Year. This began in August 1979, and will continue through February 1981. The ISEE satellites will play an important reporting role in the effort. A major new initiative from the United States in support of this international effort will be the launch of a Solar Maximum Mission (SMM) early in 1980. This satellite is instrumented for meticulous reporting of flares and other disturbances on the solar surface; its data will be supplemented from an array of other satellites and ground-based telescopes.

The next major foray toward the Sun after the solar maximum is the International Solar Polar Mission. Its two spacecraft will be the first solar mission to approach the Sun from outside the ecliptic plane and will report on the complex polar regions on the Sun. In 1979 the United States spacecraft and experiments were contracted; the other spacecraft is being developed by the European Space Agency.

Study of the Planets

Few if any years in the history of the United States space program have seen such activity and dramatic new vistas in planetary exploration as 1979. Our unmanned spacecraft visited Venus, Jupiter, and Saturn; in their passages of Jupiter Voyager 1 and 2 brought us the first views of the striking diversity of the four large Galilean moons—all of them big enough to qualify in the rapidly growing new science of comparative planetology.

Mars. At the end of 1979, almost four years after the arrival of the Viking spacecraft in the vicinity of Mars, one of the two Viking orbiters still had a supply of control gas and was returning high-quality imagery of the Martian surface. Both of the landers sent imagery and meteorological and radio science data during the year. The lander nearer the equator has been programmed for periodic interrogation during the next decade.

Venus. In the closing weeks of 1978 the Pioneer-Venus orbiter and five probes arrived at Venus; the orbiter circled the cloud-enshrouded planet through 1979. The probes descended through the atmosphere, sending back a large volume of data that will require several years of intensive analysis. Two items have been of early interest: the trace elements of the rare gases, argon and neon, in the atmosphere of Venus were an order-of-magnitude less in quantity than in Earth's atmosphere and another order-of-magnitude less than in Mars' atmosphere. Since these gases do not enter into chemical compounds, they provide relatively direct information about the original materials from which the planets were formed. The other item of interest is the large amount of sulfur that the probes encountered in the lower atmosphere of Venus.

Meanwhile the Pioneer orbiter probed the geography of the surface of Venus with its radar altimeter, sketching out at least some of the major features. Especially interesting is a large plateau, rising some 6 kilometers above its surroundings and spreading about 100 kilometers across. Such features are found on Earth but not on the other inner planets; it would seem to have been created by large-scale crustal forces.

Jupiter. The dramatic highlight of 1979 in the United States space program was the flights of Voyager 1 and 2 past Jupiter and its four Galilean moons. The more than 30,000 images returned by the two spacecraft depicted in detail the violent, colorful weather patterns in the atmosphere of the solar system's largest planet: rapidly shifting anticyclonic winds swirling around the edges of the Great Red Spot—the huge, long-lived storm twice as large as the Earth; banded polar weather systems propelled by strong east-west winds rather than by thermal convection as previously thought; winds as strong as 260 kilometers, twice the force of hurricane winds on Earth; extensive auroral displays; and cloud-top lightning discharges of much greater power than any on Earth.

Even more impressive was the diversity of the Galilean moons, all four of them near enough to the size of Mercury to qualify as planet-type satellites: bright-orange Io, pockmarked with several erupting volcanoes spewing sulfurous material over the surface; white-faced Europa, laced with thousands of intersecting fracture lines; Ganymede, larger than Mercury yet light enough in weight to be half water, with a heavily cratered surface alternating with grooved terrain; and brooding Callisto, darkest in albedo and with concentric ring remnants surrounding ancient huge impact basins long since filled in by flow of the icy crust.

The massive Jovian magnetosphere proved to be similar to Earth's in some respects—well defined

magnetospheric boundaries and tail and bow shock wave—but surprising in other respects, such as a strong magnetic flux tube arching between Jupiter and Io, perhaps contributing energy to Io's volcanism.

Now headed across the solar system, Voyager 1 is expected to arrive at Saturn in November 1980; Voyager 2 will follow in September 1981 and perhaps fly on to Uranus.

Saturn. For the first time, a spacecraft from Earth flew past the big distant planet Saturn whose spectacular rings have long tantalized viewers through their telescopes. Pioneer 11, launched in April 1973, had followed its sister spacecraft Pioneer 10 around Jupiter in December 1974 and then had sailed across the solar system to its encounter in 1979 with Saturn. Its measurements of Saturn's strong magnetic field confirmed that Saturn, like Jupiter, radiates more heat than it receives from the Sun. Though it did not penetrate the famous rings, it did find two more faint rings outside of those visible from Earth; also it confirmed that the rings absorb the energetic particles trapped by the magnetosphere, so that passage near them should be safe for Voyager 2 as it flies past Saturn on a course toward Uranus. Saturn's moon Titan is an object of much speculation because it is known to have an atmosphere; Pioneer 11 passed no closer than 350,000 kilometers from Titan, so the rather fuzzy pictures revealed little. Both Pioneer 10 and 11 will not make further planetary encounters but will depart the solar system. They will continue to be interrogated for several years for data on the composition of the interplanetary medium.

Ground-based Research and Analysis. Teams of researchers continued to sift the vast amounts of data from the Viking missions, the Venus probes and orbiter, the Voyager data on Jupiter and the Galilean moons, and the new data on Saturn. Ground-based astronomy acquired a powerful new tool in 1979 when the Infrared Telescope Facility was completed on the summit of Mauna Kea in Hawaii. The new telescope supported the Voyager encounter with Jupiter; all planets will be studied by observations of the thermal emissions of their surfaces and atmospheres. When the planets are not in position for study, the telescope will be used as a national facility for stellar astronomy.

Study of the Universe

Answers to the most profound questions about physical existence, the nature of matter, and the range of physical processes may well be found in study of the complexities of the Universe.

Research with Spacecraft. HEAO (High Energy Astronomy Observatories) satellites are the largest

and heaviest automated spacecraft yet launched by the United States space program. The series of three satellites has been instrumented to inventory and study the high-energy sources in the Universe. HEAO 1, launched in August 1977, was highly successful in surveying the entire sky to map the x-ray sources. When it reentered the atmosphere in March 1979, it had increased by four times the count of known x-ray sources. One of its findings was that a class of stars exhibiting strong x-ray emissions has very hot, active atmospheres, or coronae. HEAO 2, launched in November 1978, was designed to study in detail the most interesting of the x-ray sources identified by its predecessor. It confirmed HEAO 1's findings about the hot-surface stars but extended those findings to show that a much larger class of stars, in a range of sizes, ages, and temperatures, are unexpectedly bright x-ray sources. This finding challenges most of the existing theories on stellar atmospheres. HEAO 1 and 2 have also raised questions about the diffuse x-ray background in the Universe; this could have direct bearing on the ultimate question of how the Universe began and how it will end. Their finding indicates a widespread diffusion of x-ray sources; if the diffusion is many x-ray stars, the required mass will not exist to "close" the Universe, end its expansion, and turn it back inward toward eventual implosion; if the x-ray readings are truly diffused in enormous, very hot gas clouds, there might indeed be enough mass to close the Universe. HEAO 3, launched in September 1979, is instrumented to study gamma-ray and cosmic-ray emissions in the Universe. All instruments are performing well and the data are expected to supply many pieces for the Universe puzzle.

The International Ultraviolet Explorer (IUE), satellite, launched in 1978, performed well through 1979, its data exciting much scientific interest. With instruments from NASA, the United Kingdom, and the European Space Agency, IUE has studied the spectral lines associated with atomic radiation in the atmosphere of stars and in the interplanetary medium. It confirmed the existence of a galactic halo—rarefied, high-temperature gas extending far above and below the plane of the Milky Way.

Research from Suborbital Vehicles. Returns from balloons, aircraft, and sounding rockets continued to make meaningful contributions to technology and scientific knowledge. NASA's balloon program lofted a far-infrared telescope that measured the portion of the total luminosity of the Milky Way contributed by dust; this offers information on the rate at which stars form. In the NASA airborne research program, the Kuiper Airborne Observatory detected for the first time a major output of far-infrared molecular lines from carbon monoxide in a region where stars are forming; measurement of

these intensities is important in understanding the energy balance in star-forming regions.

Sounding rockets won a place in 1979 in the Space Shuttle program; approval was given for a development flight in 1981–1982 to demonstrate the concept of flying sounding rocket payloads off the orbiting Shuttle, to be recovered and returned by the Shuttle.

Research from the Ground. A unique double quasar has been discovered by research sponsored by the NSF. The quasar was first detected at the Jodrell Bank Radio observatory in England. At that time the object appeared to be an ordinary quasar. Then on March 29, 1979, the Kitt Peak National Observatory's 2.1-meter optical telescope found that the object was in fact two images separated by an angle of 5.7 arc-seconds. This finding was later confirmed by the University of Arizona's 2.3-meter telescope on Kitt Peak and the new Multiple-Mirror Telescope operated by the University of Arizona and the Smithsonian Astrophysical Observatory.

Although binary in appearance, the two images may be the result of light from a single quasar being split by what amounts to a gravitational lens. This would require the presence somewhere between the quasar and Earth of either a supermassive black hole or a large galaxy with trillions of solar masses.

More recently the double quasar's radio-wave image was observed on the Very Large Array interferometer radio telescope in New Mexico. Again the double image appeared. But more interestingly, one of the two quasars is actively expelling jets of matter into space. Because no similar matter is associated with its twin, the radio-wave observations indicate a genuine double quasar; perhaps no gravitational lens need be postulated. The near-identical redshifts and optical features of the two quasars do suggest a common origin.

In December 1978 three astronomers at the University of Massachusetts announced the first experimental evidence directly supporting the existence of gravitational waves. Such waves, long hypothesized but never directly observed, are in some ways similar to radio waves, but are based on the forces of gravity rather than on those of electricity and magnetism. The existence of gravity waves is one of the longstanding but heretofore untested predictions of Einstein's general theory of relativity.

The discovery came out of a four-year observing program to measure the general relativistic effects in a binary pulsar. The pulsar, located some 15,000 light years from Earth, was observed with the 300-meter-diameter radiotelescope antenna operated by the National Astronomy and Ionosphere Center. Discovered in 1974 by the same research group, the pulsar is known to be orbiting another massive object—perhaps another pulsar, or perhaps a black

hole—because its repetitive pulses of emission speed up and slow down over a period lasting a little less than 8 hours.

Einstein's theory predicts that such a system should emit gravitational waves that slowly extract energy from the orbit, thereby causing the pulsar and its companion to move closer together. As the size of the orbit decreases, the length of time required for the pulsar to complete an orbit also decreases. Relativity theory predicts that the orbital period should decrease at a rate of one ten-thousandth of a second per year. The measured amount is almost precisely this value, or about four ten-thousandths of a second since late 1974. Thus an important prediction has been verified by an application of Einstein's theory that could not have been foreseen when he developed the theory 60 years ago.

Solar flares and other manifestations of solar activity are intimately connected with magnetic fields. A central objective of contemporary solar physics is to study how these fields are generated and how they produce the spectacular phenomena associated with solar activity. The proximity of the Sun allows these problems to be studied in great detail, providing a firm foundation for hypotheses concerning similar processes in more remote objects.

Analogous of solar activity are found on many other stars. Flare stars, for example, exhibit violent outbursts similar in many respects to solar flares, but involving as much as a thousand times more energy. Most stars, like the Sun, have chromospheres and coronae, some much more pronounced than the Sun's. Recent work at Hale Observatories has shown that the activity of stellar chromospheres waxes and wanes over periods of years in a manner strongly suggestive of the solar activity cycle. It has been supposed that all these phenomena are caused by stellar magnetic fields, but until recently there was no way to directly detect and measure magnetic fields on solar-type stars.

Now, Sacramento Peak Observatory has devised a way to directly measure the strengths and areas of stellar magnetic fields. The method relies on the Zeeman effect: the shape of a spectral line formed in a gas containing a magnetic field depends on the strength and direction of the field. A magnetic field was easily detected for the first time on the dwarf star Xi Bootis A. The field strength was 2900 gauss, covering about 45 percent of the stellar surface. By comparison, the solar field strength is about 1500 gauss, covering about 1 percent of the surface. Since Xi Bootis A is a young star exhibiting much more prominent chromospheric activity than the Sun, this observation provides direct confirmation of an intimate connection between stellar magnetic fields and stellar activity. The new method is now being systematically applied to study magnetic fields

in solar-type stars, using data obtained with the 4-meter Mayall telescope at Kitt Peak National Observatory.

Study of the Life Sciences

Work with the Soviet Union included flying United States biological experiments on Soviet spacecraft plus joint ground-based clinical studies. This year's study has concentrated on finding a more authentic experimental model for the effects of weightlessness on the human cardiovascular system; an additional benefit has been standardizing test procedures that are applied to American astronauts and Soviet cosmonauts. In two sets of tests in 1979 10 subjects were studied intensively by teams of American and Soviet investigators. The data proved to be similar, despite the many differences in procedure.

Studies continued on means to maintain the health and safety of Space Shuttle crew members. To minimize any adverse effects suffered when crew members reenter Earth's gravity, NASA has been conducting tests with anti-gravity suits that inflate automatically during reentry when the flow of blood to the head decreases. Water-cooled suits and blood-volume replenishment have been developed for use on longer missions or for more susceptible passengers. The recurring problem of space motion sickness has been the subject of extensive study, and drug screening has identified several medications that relieve the symptoms with minimal side effects.

Transportation

In aeronautics and space the United States carries on extensive research and development for new transportation systems and for improving the operations and flexibility of existing systems.

Space Transportation System

The Space Transportation System represents the maturing of the Space Age—an integrated approach to space travel and exploration. It encompasses flight and ground operations, logistics, and future mission planning. The flight component is the Space Shuttle. Scheduled to make its first orbital test flight in late 1980 or early 1981, the Shuttle is composed of:

- the airplane-like orbiter, which houses the crew of from 3 to 7 persons and the payload and can maneuver in space, reenter from orbit and land on a runway, to be refurbished and fly again;
- two solid-fuel rocket boosters that fire during the ascent phase and then fall away to be recovered from the ocean and used again;

- and the external tank, which provides liquid hydrogen and oxygen to the three engines on the orbiter during the launch phase.

In April 1979 the Space Shuttle configuration passed its design certificate review and most of the qualification of flight-configured elements.

The Space Shuttle will be diversified by several supplemental systems. Spacelab, funded and developed by the European Space Agency, is a variable set of modules that can house payloads and crew members in a shirtsleeve environment, or expose instruments to the space environment from pallets. To lift payloads out of and into the orbiter's cargo bay while in orbit, a remotely operated loader-unloader arm is being funded and developed by Canada. To boost payloads from the orbiter's low orbit to higher orbits, DoD is building the Inertial Upper Stage, a three-configuration set of upper stages. Smaller boosters, to lift smaller payloads into higher orbits from the orbiter, are being funded and built by United States aerospace industries as commercial ventures.

Space Shuttle. The orbiter has been the pacing item of the Space Shuttle. Its cluster of three high-pressure, throttleable engines and its sheathing of thermal-protective tiles have had stubborn problems that have only slowly yielded to step-by-step engineering solutions. At NASA's Kennedy Space Center the first flight orbiter, Columbia, was slowly being clad in its shielding of protective thermal tiles during 1979. The second orbital vehicle, Challenger, is nearing the end of structural testing, after which it will be converted to flight hardware. Two more orbiters are in production.

The orbiter's main engine progressed slowly through its extensive program of test firings, delayed a number of times during the year by small anomalies that called for the test engine to be pulled off the test stand and partially disassembled for inspection and repair. Much more is being asked of it than of any previous large rocket engine: it is to operate at high internal pressures to produce a superior thrust-to-weight ratio; it is to be throttleable; it is to last much longer than previous engines; and it is to be reusable for many flights. This year the engine passed the mark of 50,000 seconds of test-firing time toward the goal of 80,000 seconds prior to orbital flight.

Two 3.7-meter-diameter solid rockets will fire along with the cluster of three main engines during launch and ascent. As their burn is completed, they will separate from the orbiter, descend on parachutes to ocean landings, after which they will be recovered, reworked, and reloaded with propellant for another firing. The developmental firings of these motors have been completed and two of the quali-

fication firings have taken place, with one more to come. Most of the rocket segments for the boosters to be used on the first orbital flight have already been delivered to Kennedy Space Center.

The big external tank—7.5 meters in diameter by 47 meters long—is the fuel tank (liquid hydrogen and liquid oxygen) for the orbiter's three main engines during launch and ascent phases. As orbital altitude approaches, the main engines cut off and the empty tank separates and descends to a landing in a remote ocean area. The first flight tank has already been delivered to Kennedy Space Center; three more flight tanks are under construction for the other flights in the orbital flight-test program.

Ground Facilities. At the Kennedy Space Center, all launch facilities are completed and in place for the first orbital flight. Ground support equipment and the computerized launch-processing installations are in the final stages of completion, with software being validated. At NASA's Johnson Space Center, DoD was completing design of facilities and equipment for providing training and operational control of classified DoD missions on the Shuttle. At Vandenberg Air Force Base, California, DoD began construction in 1979 of the nation's second Shuttle launch and landing site, this one to be used by both civil and military missions that require polar orbit. Work neared completion on the design of unique equipment and installations and acquisition of launch processing and computer software.

Planning for Operations. When the Space Transportation System completes its orbital test flights and becomes operational, many new activities will become possible in space. Payloads can be placed into orbit and serviced there or returned to Earth for refurbishment and reorbiting. Experimenters can accompany their experiments into space and operate them in a shirtsleeve environment or control them remotely while the instruments are directly exposed to the space environment. Small, discrete experiments will be possible as well as large payloads. The first few years of Shuttle operations are fully booked by a wide range of civilian and military agencies of the United States government and by domestic and foreign governments and commercial organizations. An additional nine commercial and foreign users made payments or deposits on reservations this year.

NASA published in the *Federal Register* the policies on user charges that will be in effect for the first few years of Shuttle operations. They describe the price structure and conditions under which NASA will furnish launch services and flight hardware. The program begun in 1977 to provide Shuttle services for small, self-contained payloads continued to attract much interest in 1979. By the end of the year more than 300 individual payloads had

been approved and confirmed by advance payments. Individuals, educational institutions, and industries can fly these small payloads that require minimal support from the Shuttle or the crew.

Spacelab. Funded, designed, and developed by the European Space Agency, Spacelab is a significant contribution to the versatility of the Space Transportation System. Built to fit into the cargo bay of the orbiter in any of several modular combinations, Spacelab will provide access to space for experimenters from many nations in disciplines such as space technology, meteorology, biology/medicine, communication/navigation, space processing, and material science. The Spacelab module offers experimenters a shirtsleeve environment in which to work; the Spacelab pallets expose experiments directly to the space environment. The normal Spacelab mission will last 7 days, though it can remain in orbit as long as 30 days.

Under terms of the agreement between NASA and ESA, ESA will deliver the first Spacelab flight unit, an engineering model, two sets of ground support equipment, and spares to support the first two missions. NASA will provide the connective items such as the tunnel between the Shuttle cabin and Spacelab and will be in operational control. In 1979 ESA delivered the second engineering model of the pallet to Kennedy Space Center. In Germany, the Spacelab engineering model hardware is being processed, while the flight module is being assembled. Subsystem testing is more than 80 percent completed.

Progress was made on the first Spacelab payloads during 1979. NASA received the instruments to be carried on the first Shuttle payload missions and began their integration into Spacelab pallets. OSTA 1, the first mission, will be instrumented to collect Earth resources and environmental data. The second mission, OSS 1, will gather solar physics data, evaluate the ambient and induced Shuttle environment, and collect data on payload thermal control. An experiment in plant growth will be carried in the orbiter cabin. The major tests of the Spacelab module will come on the Spacelab 1 and 2 missions; these moved into final design in 1979 and manufacture of hardware was begun. All instruments have been approved and most experimenters are well into fabrication of their flight hardware.

Inertial Upper Stage. DoD continued the full-scale development of the Inertial Upper Stage (IUS), begun in April 1978. Intended to carry larger DoD payloads and NASA's geosynchronous and planetary missions from the Space Shuttle to higher orbital altitudes, IUS will also be used with the Titan III booster during the period of transition to the Space Shuttle. The first DoD launch of Titan III-IUS is scheduled for 1982; the first NASA use

of the two-stage version will be the launch of the Tracking and Data Relay Satellite in 1982. First use of the three-stage version will be the launch of NASA's International Solar Polar Mission.

Spinning Solid Upper Stages. Spinning Solid Upper Stages (SSUS) are being developed by American aerospace companies at their own expense for sale to users who need to launch smaller satellites into geosynchronous orbit. SSUS-D is sized for payloads that would use the Delta expendable booster, the SSUS-A for somewhat larger ones that would use the Atlas-Centaur. Design for the two classes was completed in 1979 and qualification programs began. Most hardware has been manufactured and is ready for assembly. SSUS-As have been ordered by NASA for launch of Comsat's Intelsat V communication satellites. SSUS-Ds will be used for NOAA's Geostationary Operational Environmental Satellites and for most commercial users.

Skylab

Skylab had been in orbit since May 1973 as the first orbiting laboratory of the United States. Expected to stay in orbit until about 1983, Skylab encountered several years of greater atmospheric density than expected—caused by an increase in sunspot activity—which shortened its orbital lifetime to 1979–1980. Ground controllers succeeded in reactivating Skylab systems and trimming its attitude but an attempt to modify its orbit by flying a teleoperator booster rocket up to it was abandoned in 1978. Because of Skylab's large size, there was some international concern about danger from descending debris following its breakup upon reentry. In the last few orbits NASA controllers made minor adjustments to Skylab's orientation and it reentered on July 11, 1979. Although some debris from the breakup landed in rural parts of Australia, there were no reports of personal injury. Some pieces were recovered for study.

Expendable Launch Vehicles

The United States space program had a total of 16 launches in 1979; all were successful, launching 18 payloads. Atlas-Centaur, Atlas F, Delta, Scout, Thor, and Titan III launch vehicles were used for space launches this year.

Research for Spacecraft Improvement

A number of research projects in materials and structures, electronics, and propulsion were conducted in 1979.

Materials and Structures. During 1979 two new insulation materials were developed for use on portions of the Space Shuttle orbiter. For use in areas

of moderate reentry heating, there is a silica-based, quilted-felt material that is flexible and reusable. For use in areas of higher heating, there is a fiber-reinforced composite insulation which is twice as strong and has greater heating resistance than present reusable insulation. In composite structures, a composite aft body flap for the orbiter was fabricated and tested; if adopted, it would lighten future orbiters by 160 kilograms, mostly because it would not require thermal insulation.

Electronics. A "multi-layer magnetic lattice file" was successfully demonstrated in 1979 by NASA. Building on technology for the magnetic bubble memory, it promises space data recorders up to 50 times the storage capacity as those in today's recorders. Fundamental research on radiation damage to silicon solar cells in space showed that thermal annealing (heating) of the damaged cells can restore 90 percent of the power loss.

DoD continued development of a fault-tolerant spaceborne computer that would minimize satellite dependence on ground stations and used magnetic bubble memory technology in progressing toward a solid-state spaceborne memory that will provide hardened, non-volatile data storage.

Propulsion. In 1979 NASA neared completion of verification testing of ion propulsion. With this entirely new form of propulsion, missions to comets and other difficult interplanetary destinations could become realities. In FY 1979 a 12-kilowatt deployable solar array underwent simulated acoustic and thermal tests prior to a test on an early Shuttle flight.

Aeronautical Transportation

Like space transportation, aeronautical transportation comprises military as well as civilian systems and those that are operational as well as those that are in development.

Operational Airborne Systems. In the United States national system of aeronautical transportation, DoD has responsibility for operational airborne systems.

FIGHTER AIRCRAFT. In January 1979 the first production F-16 multimission fighter aircraft were received by the United States and Belgium; the Netherlands received its first aircraft in June. Denmark and Norway, the remaining partners in the development of the F-16, will begin receiving aircraft in 1980. Delivery of A-10 close-air-support aircraft to tactical forces in the United States and Europe continued. By the end of 1979, over 300 of the approved 627 aircraft had been produced. Reliability and maintainability have been demonstrated to be favorable, promising low operating costs. Improvements in existing F-15 fighters are concentrat-

ing in upgrading software rather than the expensive hardware systems. Over 430 of the total order of 729 had been delivered to the Air Force. Delivery of the C and D models began in June; these feature a 1000-kilogram increase in fuel capacity. The remainder of the aircraft produced will be the C and D models. F/A-18 fighters were approved for full-scale development, with 11 test aircraft on order. Designed to provide the commander at sea with a high-performance, agile strike fighter, the F/A-18 will replace the remaining Navy and Marine F-4 Phantom fighters, and later will replace the A-7 light attack aircraft.

BOMBER AIRCRAFT. A series of improvements are under way to update and improve the effectiveness of the B-52 fleet. The navigation system is being modernized with nuclear-hardened digital systems in place of obsolete vacuum-tube systems. All avionics are being hardened to withstand electromagnetic pulse from nuclear explosions. Also the bombers are being fitted to carry the air-launched cruise missile. Other bomber-related activity is limited production of the EF-111A, designed to provide defense radar jamming in support of United States and allied air operations.

TRANSPORT AIRCRAFT. By the end of 1979, 19 E-3A airborne warning and control (AWAC) aircraft had been delivered to the Tactical Air Command out of the 34 on order. NATO has also ordered 18 of the aircraft, together with an improved computer to increase the tracking capability.

HELICOPTERS. Modernization of the large CH-47 helicopter fleet continued, to update and standardize all CH-47s and provide a medium-lift helicopter capability beyond the year 2000. Seven systems are in development for modernization; in 1980 they will be tested in three prototype helicopters. The full-scale engineering development of the advanced attack helicopter continued, with the prototype helicopters being modified to accept updated target-acquisition and night-vision systems. Airborne firings of the Hellfire ballistic missile from the helicopters began in 1979, progressing through guided launch to autonomously designated launch.

CRUISE MISSILES. The AGM-86B and AGM-109 air-launched cruise missiles made 10 flights each in 1979 in a competitive "flyoff." Source selection is expected in March 1980. A production rate of 40 per month is planned, complementing the B-52 modification rate. The ground-launched cruise missile, intended to bolster theater nuclear firepower, is being procured in an amount of 560 for deployment in Europe. Essentially this puts the Tomahawk cruise missile into a system with an air-transportable, mobile ground component. The advanced strategic air-launched missile, designed for use with the present and future strategic bomber force, is a

long-range supersonic missile that can neutralize the Soviet interceptor threat against United States warning and control aircraft as well as take out defenses and primary targets. A flight-test program was begun in 1979 to validate the ramjet propulsion system.

Operational Airway Systems. The Federal Aviation Administration (FAA) of the Department of Transportation is responsible for maintaining and operating the National Aviation System. NASA assists with research and development for the airborne portions of the system.

AIR SAFETY. With studies, research, and tests, FAA continued to improve aircraft equipment and to improve the competence to handle safety-related problems for aircraft on the ground, on takeoff, and on landing.

As a result of research into problems of controlling aircraft traffic on the surface area of airports—runways, taxiways, etc.—particularly in bad weather, a new radar has been developed. The ASDE-3 (Airport Surface Detection Equipment) is better able to detect stationary aircraft and track taxiing aircraft in all weather conditions. A prototype ASDE-3 began testing in August at the National Facilities Experimental Center.

To provide warning of potential wind-shear problems during takeoffs or landings, the FAA has developed and tested the Low-Level Wind Shear Alert System. Remoted anemometers are mounted 6 to 12 meters above the ground in the approach and departure corridors at busy airports. When a wind vector difference of as much as 28 kilometers per hour develops between any of the remoted anemometers and the centerfield anemometer, air traffic controllers relay the information to all aircraft in the airport traffic pattern. The system is now operational in 24 airports.

A wind problem generated by large aircraft has been of increasing concern: wake vortices—strong rotational wind gusts—trail behind large jet aircraft as they approach and land. Aircraft following them, especially smaller ones, are endangered. For their protection, the separation distance between landing aircraft has been enlarged; this reduces the airport's traffic capacity. A prototype Vortex Advisory System was evaluated in 1979 at Chicago's O'Hare International Airport and is expected to be commissioned early in 1980. Its network of anemometers in the runway approach zones assesses wind conditions; decision can then be made when aircraft separation can be set at 5 kilometers.

AIR TRAFFIC CONTROL. Since 1971, DoD, DOT, and NASA have jointly worked to develop a microwave landing system (MLS). Operational and economic advantages argue in favor of equipping the

national air network with a universal system that can handle civil and military air traffic for the remainder of this century.

The same deficiencies in the existing Instrument Landing System (ILS) that motivated the United States to develop a new landing system also affect the other nations of the world and generated wide support for a new international standard. The International Civil Aviation Organization (ICAO) set out to select and standardize an international system. Several competing systems were studied and given field tests. In April 1978, the United States entry, the Time Reference Scanning Beam, was selected by the ICAO as the new international standardized system. Of the three versions of MLS to be developed, the basic narrow aperture and the small community systems have been tested and evaluated. The third system, the basic wide system, designed for major airports, began testing in 1979 at NASA's Wallops Flight Center. Meanwhile small community systems will be installed at Philadelphia International Airport, Washington National Airport, and Bader Field (Atlantic City) early in 1980; a basic narrow system has already been installed at Washington National Airport. These will provide operational data for incorporation into handbooks and other regulatory material.

Another system being evaluated is the Discrete Address Beacon System; the last of three prototypes was received in 1979 and joined the other two in the vicinity of FAA's National Aviation Facilities Experimental Center. The new beacon system provides discrete identification of individual aircraft by use of code-numbered transponders in the aircraft. This automatic identification is increasingly important as the national airway network becomes more automated.

AIRWAY MODERNIZATION. As part of the automating of the 20 air traffic control centers, FAA in 1979 let a contract for development of an engineering model of an Electronic Tabular Display System. It is to provide more efficient display and update of flight plan data than the current, largely manual, paper flight-progress strips. In 1980 the engineering model will be installed at the National Aviation Facilities Experimental Center for test and evaluation.

Similar automation is in process for the air controllers at airport terminals. The Terminal Information Processing System (TIPS) uses computers and associated electronic displays to process and display flight data automatically. A prototype TIPS system is in development; in 1980 it will be installed at the National Aviation Facilities Experimental Center for test and evaluation.

Research for Aeronautics Improvement

Essential to a competitive national aviation establishment is a continuing flow of innovations and refinements. While FAA develops improvements in the National Aviation System, NASA and DoD seek improvements in present and future aircraft.

Engines. For current transport aircraft, NASA's research focused on improving the technology of individual components to make them save fuel and be more durable. In fundamental research with ceramics, NASA tested an abradable ceramic seal for turbine engines which could reduce the wear of turbine blade tips by a factor of 10, with a 2 percent saving in fuel consumption. From its list of 16 improvable components, NASA completed work on 7, of which 4 are already in production in the aircraft engine industry. DoD pursued two programs; one assessed core components of engines under realistic test conditions, searching for improved reliability and maintainability. This year the program conducted tests of a new generation of gas generators and of variable-area, high-temperature turbines that used advanced materials. The other program studied the interaction of high-pressure engine components, such as turbine engine cores, with low-pressure fans, compressors, and fan turbines in a full-scale technology demonstrator engine.

Aerodynamics. NASA continued research on reducing energy use in transport aircraft. In fundamental research, NASA achieved the first computational solution predicting and explaining the unsteady flow of air over wings and other lifting surfaces at transonic speeds. In a joint Air Force-NASA test, a KC-135 tanker aircraft was flown in 1979 with winglets; when completed in 1980, the test program is expected to show the winglets decrease drag by 6–8 percent. Wind tunnels have tested a new wing flap configuration that increases maximum lift by 30 percent. In research on removing the turbulent air flow over wing surfaces, NASA built wing panels in 1979 with slots and porous surfaces to remove air turbulence.

Structures. In recent years NASA and DoD research on aircraft structures has concentrated on composite structures—structures fabricated from the family of synthetic materials that are stronger, or lighter, or more heat resistant than conventional materials. In 1979 NASA identified newer, tougher graphite/epoxy materials that withstood impact tests to almost twice the strain that presently used composites can tolerate. Since much remains to be learned about the lifetime performance of these new materials, the testing approach has been conservative, beginning with small, less stressed portions of larger structures, and building up a design data base from static, fatigue, and sonic experience. For sec-

ondary structures, NASA completed its DC-10 rudder tests in 1979, and the structure was accepted by FAA for airline service. Airline service began for five shipsets of B-727 elevators. For medium sized primary-structure components, the design phase was completed. The primary B-737 stabilizer components passed static, fatigue, and fail-safe tests and the first full-scale B-737 stabilizer was fabricated.

DoD was testing in wind tunnels large-scale models of the forward-swept wing, the feasibility of which derives from the characteristics of advanced composite materials. Also under test were adhesive bonding as a replacement for riveting of primary structures in aircraft, as well as the use of cast aluminum for primary structures.

Improvement of Long/Short-Haul Aircraft. NASA's research on technology for future long-haul supersonic aircraft centered on propulsion, aerodynamics, and structures that would make possible a cost-effective, environmentally acceptable aircraft. In 1979 two engine concepts were tested, high-lift devices improved the low-speed efficiency of swept wings, and research in titanium structures led to design and fabrication of a titanium tail for a small supersonic aircraft. In research on quiet short-haul aircraft, NASA continued flight testing the research aircraft. By the end of the year it was apparent that the aircraft was performing very close to design predictions, particularly the very low noise characteristics necessary for short takeoff and landing operations.

Aircraft Fire Safety. FAA used a C-133 fuselage to simulate a wide-body jet in a series of fire experiments to determine survivability patterns from post-crash fires fed by spilled fuel outside the fuselage. Since many of the worst fires arise from fire balls, caused by spilled fuel forming fine, mist-like particles, FAA experimented with additives that would inhibit such combustion.

Aviation Security. FAA research and development on means of deterring air-travel terrorism and sabotage concentrated in 1979 on improved techniques for detecting explosives in baggage and other items. A transportable bomb detector was constructed and prepared for testing in airports. Authorities were provided with vapor characteristics for a broad range of explosives; these can be used for evaluating screening devices in an airport environment.

Space Energy

The accepted means of producing or storing electric energy in space have been solar cells, batteries, fuel cells, and radioisotope thermoelectric generators. Space missions now being envisioned by DoD

and NASA will call for much higher energy levels extending over mission profiles of several years. Studies also continued on the possibility of collecting large quantities of solar energy in space and beaming it to Earth as a supplemental power source.

Energy for Use in Space

Radioisotope Generators. The Department of Energy (DOE) has been developing a new form of radioisotope thermoelectric generator for NASA's Galileo planetary mission. During 1979, the version of the generator that has been very effective in DoD's Lincoln Experimental Satellites and NASA's Voyager 1 and 2 planetary missions was upgraded with an improved alloy for the fuel capsules and use of composite materials in the heat-source aeroshell.

The International Solar Polar Mission, operated jointly by NASA and the European Space Agency, plans to launch two spacecraft in 1985, each with a power requirement of 275 watts two years after launch. This requirement is expected to be met with thermoelectric generators comprising 18 heat sources.

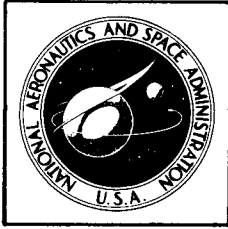
Dynamic Power Systems. For electric power in space greater than 500 watts, dynamic power systems are expected to take over from the static selenium conversion systems because they offer improved endurance, efficiency, weight ratio, and reliability. In tests in 1978, the Organic Rankine Cycle was

chosen for further development, with expected efficiencies in the range of 18–25 percent.

Reactor Power Systems. Studies by DoD and DOE predict that DoD space missions in the late 1980s will have electric power requirements of 10–100 kilowatts. Consequently, a technology development program for a space reactor was begun in 1979. In five years it is to develop component technology that merits further funding by the user agency. Civil applications that might need this order of electric power include satellite power systems, electronic mail, and advanced television coverage.

Energy for Use on Earth

Satellite Power System. The concept of beaming solar energy from a point in space to receiving antennas on Earth has been studied since 1968. In 1977, DOE and NASA began a broad study in which DOE was to set the basic ground rules and investigate the many areas of potential effects; NASA was to investigate the technology demands and opportunities. DOE has identified and is studying some 40 generic systems—radars, satellites, computers, etc.—that could be affected; sciences and humanistic effects are also being studied, as well as preliminary estimates of cost, health and safety, and land requirements. The joint study made good progress toward its reporting date in 1980.



National Aeronautics and Space Administration

Introduction

The mission of the National Aeronautics and Space Administration (NASA) is the planning, direction, and conduct of civil research and development in space and aeronautics. These activities are shared or joined by a number of other agencies of governments—foreign, Federal, state, and local—with research or operational interests in these fields. Space activities that are solely military are conducted by the Department of Defense (DoD); in aeronautics, NASA supports DoD with research and test data to improve performance and safety of current and future military aircraft.

NASA's long-standing goals in space have been the development of technology and techniques that make space operations more effective; development and demonstration of an enlarging range of practical applications of space technology and data; and scientific investigations of the Earth and its immediate surroundings, of the natural bodies in our solar system, and of the origins, entities, and physical processes of the Universe. In aeronautics, the goals have been improvement in aerodynamics, structures, engines, and overall performance of aircraft, to make them more efficient, more compatible with the environment, and safer.

Applications to Earth

In applying space research and technology to specific needs of the nation and the world, NASA programs made substantial progress in 1979. Emphasis continued on improving technology for space communications, observing Earth to assess its environment and resources, and experimenting in space to acquire new knowledge about materials.

Communications

NASA has carefully mapped a path for a new phase of satellite communications research and development. The program has four distinct and related facets: advanced research and development,

public service communications, advanced applications of satellite communications techniques, and technical consultation and support.

Advanced Research and Development. Intensive interaction with suppliers and users of satellite communications identified the highest priority items for future applications—items enhancing the communications capacity of each location along the geostationary arc 33,000 kilometers out from Earth. That enhancement will come from multiplying the use of presently employed frequency bands and the opening of new bands. The multiplying effect will come from on-board switching systems, while the new bands are obtained by developing new components and techniques.

To guide the communications R&D effort, NASA's Lewis Research Center contracted with two major communications common carriers to project predictions of satellite communications traffic through the year 2000. Their results showed traffic demands exceeding the capacity of conventional satellites in the early 1990s. Technology appropriate to a new generation of satellites is being defined to meet these demands.

Multibeam antenna research is proceeding in three frequency bands: at 30–20 GHz, 1.5 GHz, and 14–12 GHz. The 30–20 GHz band has five times the allocated bandwidth of the more conventional 6–4 GHz or 14–12 GHz bands but is hampered by more severe propagation effects. Means to counteract such effects will be a major element of NASA's investigations over the next few years. The 1.5-GHz activity is an adaptive multibeam phased array under development, managed by the Lewis Research Center. The 14–12 GHz research is being performed under contract to Langley Research Center. A remarkable 15-beam antenna, with a capability to provide a theoretical frequency reuse rate of 7.5 times, is presently undergoing antenna range tests.

Work is also continuing on more efficient uses of the spectrum. Under way at Ames Research Center is laboratory work on a prototype system that can greatly reduce the bandwidth of digitized television signals. Using inexpensive integrated circuits, the prototype provides viewer-perceived quality al-

most identical to that obtained with conventional systems employing 6 to 10 times as much bandwidth.

Public Service Communications. In 1979 NASA completed two of the most successful and significant programs in the development of satellite communications—NASA's Applications Technology Satellite 6 (ATS 6) and the Communications Technology Satellite (CTS), developed jointly with Canada. Both greatly exceeded all mission objectives. Meanwhile ATS 1, launched in 1966, and ATS 3, launched in 1967, continue to provide important communications service after more than a decade in orbit. ATS 1 serves the Pacific Basin, largely through the Peacesat program, delivering educational, health-care, and even life-saving information.

ATS 6 demonstrated the feasibility of large space-deployable antennas, three-axis stabilization in geostationary orbit, and television broadcasting from space. CTS pioneered the use of new frequencies in the 14–12 GHz range, and was the first high-powered broadcasting satellite—a model for things to come in many parts of the world. Opening this new frequency paved the way for the Japanese BSE, the Canadian Anik-B, Intelsat V, and the SBS satellites—all built in the United States. The CTS satellite further provided the operational basis for future broadcast and fixed-service satellites to be used in Canada, Europe, the Mid-East, and Asia in the 1980s. These satellites may now be built in Canada, Europe, or Japan as foreign industry gains strength.

In international cooperation in space, CTS demonstrated how two nations can share in the development of operations to meet regional needs. Canada designed and built the CTS; NASA's Lewis Research Center supplied the key component, a transmitting tube ten to twenty times more powerful than those on other such satellites. The powerful transmitter made possible much smaller, less expensive, and more portable ground receiving equipment.

Most importantly, ATS 6 and CTS demonstrated the value and significance of user-oriented applications of space technology. By delivering improved health services in Alaska; teacher education in Appalachia; classroom enrichment in the Rocky Mountain states; emergency communication in many remote areas; video teleconferencing and educational television in India, Puerto Rico, and elsewhere, the satellites pioneered entirely new services and proved the value of satellite communications to and for vast groups of people.

The most recent practical demonstrations of the value of such systems occurred in September 1979 when state and local authorities in Mississippi, Alabama, and Louisiana requested the use of ATS 3 for communications from emergency medical services during hurricanes David and Frederic. During Hurricane Frederic, the township of Richton, Mis-

issippi, used the ambulance mobile unit to call through ATS 3 for a shipment of parts for the local hospital's emergency generator and to inform the civil defense headquarters in Jackson about problems of water supply. A portable base station was used in Pascagoula for backup communications when primary power was lost and a leaning microwave tower carried emergency communications traffic. The portable stations were supported by primary and backup emergency ATS 3 base stations established in Hattiesburg and Jackson, Mississippi; Malabar, Florida; and at General Electric in Schenectady, New York.

NASA is also helping the Public Service Satellite Consortium and the Appalachian Regional Commission in changing over from NASA experimental satellites to self-sustaining operations on commercial satellites.

NASA is also assisting the recently formed National Telecommunications and Information Administration of the Department of Commerce. Goddard Space Flight Center has contracted for the development of a computer model of costs for public services traffic. The model permits analysis of various combinations of uplink and downlink satellite configurations, Earth terminals, terrestrial links, end user costs, studio costs, and transponder types, as well as administrative, operations, and maintenance costs. The public service user learns the initial, recurring, and amortized costs, as well as intermediate (city-by-city) and summary (total system) results. The computer model will be a valuable tool in analyzing the economic feasibility of future public service communication systems.

Goddard Space Flight Center has contracted for development of a low-cost (approximately \$10,000) video receive-only terminal at 12 GHz for public service applications. One of the subsystems in the terminal, the solid-state receiver, is a unique low-cost unit developed earlier. The terminal will be a benchmark in the development of low-cost U.S.-built instrumentation for public service users. Activities such as those so successfully proven in the ATS 6 and CTS programs will be expanded to thousands of users as private industry adapts NASA-developed technology to its needs.

Advanced Applications of Satellite Communications Techniques. The communications techniques originating in ATS 6 and CTS activities also have other applications such as search and rescue, navigation, and position location. The satellite-aided Search and Rescue (SAR) project is proceeding on schedule toward a projected first launch in the spring of 1982. The Memorandum of Understanding among the U.S. Coast Guard, NOAA, Air Force, and NASA was signed in December 1978; the one among Canada, France, and the United States in

August 1979; and, subject to confirmation, the one between the SARSAT parties (Canada, France, and the U.S.) and the U.S.S.R. in November 1979.

Navigation-related applications studies, involving Loran-C and the Global Positioning System, were conducted in cooperation with the Coast Guard, NOAA, and the Maritime Administration. Convincing study results and a low-cost experiment conducted in the Chesapeake Bay showed present technology to be adequate for an operational system. As a result, costly field experiments are unnecessary, permitting instead advanced studies of the relevance of advanced technology to navigational applications.

Technical Consultation and Support. Approximately every 20 years a general World Administrative Radio Conference (WARC) is held in Geneva to reassess international radio regulations. The most recent conference was held in late 1979; it included a review of frequency allocation, technical standards, frequency-sharing criteria, and coordination procedures for space and terrestrial telecommunications and remote sensing.

NASA completed more than 100 technical studies and papers, conducted extensive propagation and radio frequency interference measurements, and participated in or chaired many WARC preparatory committees and working groups.

The propagation studies performed in support of WARC have led to several major accomplishments: (a) a global rain attenuation model for frequencies above 10 GHz; (b) the first long-term continuous (three-year) data base for the development of 12-GHz systems; (c) a propagation-effects predictive model for 10 GHz through 100 GHz (attenuation, depolarization, and diversity); (d) the first model of antenna-gain degradation caused by adverse propagation effects from 2 GHz to 30 GHz; and (e) the first cross-polarization degradation model for 12-GHz satellite systems.

Data System

The demand for combinations of data has fostered awareness of the rapidly changing relationship of spacecraft instruments to data users. In the early years, and in a few limited examples today, a single principal investigator would be concerned with the data produced by an instrument (a one-to-one relationship). As instruments—such as the Multi-spectral Scanner on Landsat—have become more powerful, one instrument has come to serve the needs of numerous users (a one-to-many relationship). In the future, many users will each require the data from many instruments (a many-to-many relationship). The differing needs of the various users, the differing characteristics of the various instruments, and the widely disparate data bases to

which the users will require access are major challenges of the future.

NASA is conducting a feasibility study for an applications data service to examine protocol standardization, a transportable software system for data base management, and data format compatibility among data bases and networks. The first steps to be taken are the identification of suitable pilot projects upon which the data service can be overlaid.

Environmental Observations

Upper Atmosphere. Nimbus 7, launched in October 1978, provided extremely useful data throughout 1979. Its Total Ozone Monitoring System provided the first global maps of total ozone with high spatial and temporal resolution. This is the first time one has been able to study short-period dynamic effects in ozone distribution; a series of these measurements will help provide the information needed to detect long-term, globally averaged ozone changes in the atmosphere, whether natural or man-made. Decisions involving freon refrigerants or high-flying aircraft may hinge on how well we can understand their effects on the ozone layer.

The final total ozone results from Nimbus 4's Backscatter Ultraviolet (BUV) instrument have been compiled for the first two years of operation and vertical profiles of ozone in the stratosphere were being made available in late 1979. These data, plus results being obtained from the Nimbus 7 BUV, are complemented by the measurements of temperature, nitrogen-containing species, water vapor, and ozone from the Nimbus 7 Limb Infrared Monitor of the Stratosphere experiment. This information fills in another part of the puzzle of ozone production and destruction.

Aerosols in the stratosphere also play an important role in chemistry and in the amount and spectrum of solar radiation that drives the photochemical processes. On February 18, 1979, NASA launched the Stratospheric Aerosol and Gas Experiment (SAGE) aboard a Scout rocket from Wallops Flight Center, Virginia. The preliminary results on aerosol and ozone profiles agree well with results from soundings or aircraft underflights. The stratospheric Aerosol Measurement experiment aboard Nimbus 7 has also provided information on aerosol extinction as a function of altitude. Repetitive observations over a longer period will enable us to determine the effects, if any, of aerosols on climate.

Lower Atmosphere. Through an agreement with the National Oceanic and Atmospheric Administration (NOAA), NASA provides research and development support for weather satellites. In the past fourteen months the prototype and the second of a new series of near-polar-orbiting satellites, Tiros-N

and NOAA-A, have been launched. They have produced a combined total of twenty months of improved meteorological data.

NASA continues to participate with NOAA, the National Science Foundation (NSF), and others in the Global Weather Experiment as part of the Global Atmospheric Research Program (GARP) involving more than 140 nations. The results represent the most comprehensive data base ever compiled on the limits of predictability for satellites in weather forecasting. This set of coordinated global weather data should increase our knowledge and enable improved weather predictions.

Theoretical programs are continuing work on understanding the limits of forecasting and the sensitivity of the forecasting process to the kind of data provided by satellites. As part of this activity NASA is investigating advanced temperature and pressure sounders and wind-measuring techniques. If satellites can observe these characteristics globally, then modelling of the atmosphere can begin to predict its future state and motion. Studies show these are the areas offering the greatest potential payoff in weather forecasting.

Improved prediction of severe storms is of major concern to weather forecasters. NASA, NOAA, and NSF conducted an experiment last spring in Oklahoma, the Severe Environmental Storms and Mesoscale Experiment (SESAME). The first day of the observing period was April 10, 1979, when severe weather was predicted—but not necessarily tornadoes. As it happened, this was the day of the Red River Valley (Wichita Falls) tornado outbreak. The intensive data collected that day will provide critical information on events that precede small-scale severe storms.

The study group of the NASA-Space Activities Commission of Japan completed its deliberations in 1979. It recommended steps toward a number of projects in space applications and science, including use of the Goes-A satellite and Japan's geostationary meteorological satellite in an attempt at stereographic measurement of cloud heights over the Pacific—cloud heights offer clues to the behavior of the storms they accompany. Other near-term prospects include a study of ocean winds and waves, using existing satellite and surface-truth data.

Other environmental observation techniques under way or under study include using a camera for observing lightning phenomena from space; use of satellite imagery to track air pollution from space, and aircraft-based lidar to measure pollutant ozone and particulates, both as part of a multi-year agreement with the EPA; and the Measurement of Air Pollution from Satellites experiment to measure carbon monoxide in the troposphere.

Ocean Surfaces

Despite rapid developments in electronics, computers, and miniaturization over the past decade, the realization that ships, aircraft, and buoys will never be numerous enough to provide a synoptic view of the oceans' surfaces has been a major obstacle to oceanographers. Remote sensing of the oceans has been proved by several techniques tested on Nimbus 7, earlier Nimbus satellites, and Goes 3 as well as Seasat. The complement of microwave instruments flown on Seasat demonstrated the operational potential of ocean remote sensing. Seasat results, primarily from the Gulf of Alaska Seasat Ground-truth Experiment, proved that measurement objectives can be met: surface wind accuracies of ± 2 meters per second surface, topography with a precision of ± 10 centimeters, and significant wave height of ± 10 percent.

Climate. Climate involves the long-term and spatially extended collection of all the environmental variables studied in the atmosphere and oceans. NASA has given special attention to assisting NOAA's National Climate Program Office in developing a long-range program responsive to the National Climate Program Act of 1978. NASA's evolving program emphasizes the application of space observations to improved understanding of climate influences and trends.

This year NASA initiated a special study of aerosol effects on climate, including theoretical studies and measurements of aerosols in the atmosphere. Theories predict a large volcanic eruption can inject enough material into the atmosphere to cause changes in the Earth's surface temperature.

SAGE, whose launch was mentioned earlier, observed the violent eruptions of the volcano La Soufriere in the Caribbean in April 1979. An aerial photograph of the eruption and two profiles combining data obtained from an airborne laser instrument and a preliminary inversion of SAGE data showed heavy aerosol concentrations at 18 kilometers altitude in both profiles. A number of such events have been documented in the past, but SAGE, in conjunction with similar measurements acquired by Nimbus 7, offers the first remote sensing capability to measure quantitatively such phenomena and globally map the spreading volcanic veil.

Tracking aerosol dispersion from such well-characterized events as the La Soufriere eruptions gives a useful insight as to how pollutants might also be transported globally. Thus, planners in the future may be able to site industrial centers with high air-waste by-products so as to minimize the effects on other geographic areas.

The Sun's total energy output is the most critical external force affecting Earth's climate. Until recently the assumption has been that the sun's energy output is constant—indeed, the quantity of energy passing through a unit area at the mean Earth orbit, per unit of time, is called the "solar constant." Recent measurements have provided the first direct evidence that this quantity may vary. A comparison of NASA sounding-rocket measurements of the solar constant made in June 1976 and again in November 1978 revealed a 0.4 percent increase in the solar constant over two and a half years. Initial data analysis and our present understanding of climatic models indicate that such an increase could produce a one-half degree Celsius change in Earth's surface temperatures, with an impact on crop production, ice coverage, and global precipitation patterns.

Resource Observations

The most significant gains in land observations were in agriculture. It was clearly demonstrated that remotely sensed data can be used to distinguish between spring wheat and barley as well as between corn and soybeans.

AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing), the long-term agriculture research program initiated on October 1, 1979, went through a detailed planning phase during the past year. This comprehensive interagency program was developed by a task force led by the Department of Agriculture (USDA). Eight teams representing the participating agencies will carry out research and testing. In addition to overall leadership, the USDA will provide direct leadership of five of the teams: Early Warning, Domestic Crops and Land Use, Renewable Resources, Soil Moisture, and Conservation/Pollution. NOAA will lead the Crop Yield activities and NASA the Supporting Research and Foreign Commodity Production Forecasting. The USDA will provide an independent user evaluation group to expedite implementation of the appropriate technology in routine operations and assess its value.

A major portion of this past year's effort has been devoted to ensuring continuity of remotely sensed data for researchers and operational users.

Requests for Landsat data during 1979 reflect increasing worldwide interest in applying the technology to environmental and resource-management problems. The Landsat ground stations in India and Australia began receiving test data in 1979 and will become operational in 1980, bringing the number of foreign stations to eight in seven countries. Argentina's station is under construction and scheduled to become operational in 1980. Thailand has taken

the first step by requesting construction bids for a station. Negotiations were conducted with the People's Republic of China, which is to purchase a Landsat-D ground station from United States industry under the United States-China Understanding of January 31, 1979. Chile, Kenya, New Zealand, Romania, South Africa, and Upper Volta have expressed interest in establishing a data-receiving capability. Requests for coverage from other countries continue at an unprecedented level. Among users in the United States, the largest demand is for agricultural studies, especially during the growing season when repetitive coverage in nine-day cycles and rapid data delivery offer successful crop monitoring and yield prediction.

In June, at the request of the U.S. Coast Guard, NASA began regular Landsat coverage of the oil spill off the Yucatan coast. Imagery of the entire Gulf of Mexico was supplied on a rapid delivery basis to the Coast Guard, NOAA, and USGS teams dealing with this disaster. Copies of all images of the spill were sent to the Mexican government on request. The Coast Guard used the Landsat data for broad, synoptic surveillance and to determine direction of movement of the spill.

Renewable Resources. The emphasis in space-data research for renewable resources has been on developing and testing of techniques for extracting from remotely sensed data information which could improve the management of the nation's agricultural, forestry, rangeland, and water resources.

Landsat data are greatly increasing the utility of geobased information systems for agricultural studies. A regional program demonstration with the state of Iowa addressed the increased soil erosion that sometimes follows the conversion of pasture land to row crops—for example, on high slope terrain with unstable soils. Landsat-derived agricultural land-use changes were combined with digitized soil maps and terrain data in a georeferenced information system to calculate expected erosion and to identify potential problems, thus focusing the field inspection program. This success and related projects were instrumental in passage of a state legislative appropriation of \$125,000 for the Iowa Geological Survey to purchase a state system for continuing Landsat applications work. In Florida, Landsat inventories of agricultural land and water resources are providing data for assessing the impact of planned industrial development. Florida is also planning to develop a statewide Landsat-geobased information system.

An example of efforts in transferring the use of remote sensing for crop identification and acreage assessments to the private agribusiness community was the initiation of an Applications Pilot Test with Cotton Incorporated, a private research and market-

ing organization supported and funded by U.S. cotton growers. Test sites in California, Mississippi, Alabama, Arizona, Texas, and Brazil will be used to develop an automated cotton-acreage inventory system using Landsat data.

Cooperative forest inventory demonstration projects have been completed in California, Montana, Hawaii, North Carolina, South Carolina, and Florida.

The California Department of Forestry was required by state legislation to produce a total inventory of forest lands in the state by August 1, 1979, with updates every five years. The department selected Landsat technology because of lower overall costs and the relative ease of updating the data. Land cover and forest classes were derived from a digital Landsat mosaic of the entire state.

Commercial use of Landsat techniques by the private sector has been adopted by the St. Regis Paper Company. The company is implementing a digital Forest Resource Information System which combines Landsat imagery with conventional map graphics and tabular information, permitting rapid update of forest inventory and monitoring of changes.

NASA has also begun development of an Automated Resources Inventory System in conjunction with the Navajo Nation to assist them in assessing the potential of their land. A technique for inventorying and monitoring vegetation using Landsat data is being developed; results are independently verified by the Navajos at random test sites. The method has proven to be 86 percent accurate. This new information will be added to their digital data base, along with soils and terrain data. Extensive familiarization of the Navajos with Landsat techniques and the data base has been completed; they are implementing image analyses on a computer facility at their community college.

Research in water resources is aimed at developing remote sensing techniques for monitoring soil and snow moisture. Exploratory experiments have been performed with visible, thermal infrared, and microwave sensors on the ground, in aircraft, and on spacecraft. Concurrently NASA is developing surface runoff and snowmelt hydrologic models using remotely sensed data. Such models will improve water and irrigation management methods for planning the water supplies and irrigation and for control of runoff and reservoir levels.

Water-related problems have been a major element in a Florida demonstration project where Landsat data are being used to delineate land cover in the Apalachicola River Basin so as to understand the impact of current and planned agricultural and industrial activities on the river and for possible designation of the river as a national estua-

rine sanctuary. In the Choctawhatchee Bay an existing hydrologic model containing Landsat data is being used to determine the extent to which urban development has caused water shortages in the Ft. Walton area. A Landsat-derived basic vegetation inventory is part of an impact assessment for a proposed superport at Port St. Joe.

A water management and control verification test in cooperation with the Corps of Engineers has been completed. It shows a savings of 50 to 80 percent in survey costs per watershed. As a result of the test, the Corps of Engineers plans to implement Landsat techniques operationally.

Non-Renewable Resources. Development continued of a national long-range plan to address those problems in non-renewable resources to which space technology can be applied. This plan builds on the results of the Applied Research and Data Analysis program and, in particular, the Geosat Test Case Project. In this project, NASA scientists are working closely with industry and university geologists to evaluate the usefulness of remote sensing techniques in the reconnaissance phase of ground-based exploration. Aerial and satellite data have been obtained for twelve test sites in areas containing known deposits of copper, uranium, and petroleum. The joint data analysis program is proceeding well.

As part of the studies on uranium exploration, the test site at Copper Mountain, Wyoming, was overflown with an aircraft multispectral scanner. Subtle patterns of iron oxide stains were detected over known uranium deposits, stains that are difficult to identify in ground surveys or conventional aerial photos. A similar pattern was discerned in a nearby area which had previously been considered barren, and a prediction of potential mineralization was made based on the aircraft multispectral data. Independently, geologists from the Rocky Mountain Energy Company, which has mineral rights in the area, had studied the area from the ground and found sufficient evidence of mineralization to stake a claim. Efforts are now underway to investigate the relationship between the alteration staining phenomenon and the presence of uranium-enriched rock.

These exploratory investigations demonstrate that remote sensing techniques may be used for geological reconnaissance surveys leading to the identification of mineralized areas and, perhaps, significantly increase the efficiency of exploration surveys.

Magsat, the first spacecraft specifically designed to conduct a global survey of Earth's vector magnetic field, was launched in October 1979. This satellite was placed into a significantly lower orbit than previous magnetic field-measuring satellites to provide more detailed and precise information about

the nature of magnetic anomalies within the Earth's crust. These anomalies are directly related to crustal structure. Magnetic-anomaly mapping will help improve large-scale models of crustal geology, enhancing the capability to conduct regional mineral assessment studies in remote unexplored areas.

Geodynamics. Space data are used in geodynamics to improve understanding of dynamic processes within the solid Earth, through observation of crustal movements and deformations. Laser ranging to the moon and to artificial satellites, and very long baseline microwave interferometry (VLBI) techniques are being used to complement and extend ground based observations using conventional surveying techniques.

Since 1972 NASA has periodically used satellite ranging systems to detect changes in the distance between selected points on opposite sides of the San Andreas Fault, the boundary between the North American and Pacific tectonic plates. The fourth data phase was completed earlier this year and the data are now being analyzed. Previous analyses indicated the plates are sliding relative to each other at a rate of between six and twelve centimeters per year.

Improvement in the measurement techniques is continuing. Mobile lasers (Moblas) have been installed at four VLBI stations for intercomparison of long baselines by VLBI and laser-ranging techniques. A second-generation mobile laser ranging unit mounted in a standard truck has been completed by the University of Texas and will offer much greater mobility. This unit will be deployed by the end of the year and will be able to visit twenty-five sites per year in the western portion of the United States. It and other units will be used to map the deformation of the Earth's crust by the force generated by colliding plates.

Moblas units are now operating in Australia, American Samoa, and Kwajalein Island. These and other fixed lasers at worldwide locations form an international network for global observations of tectonic plate stability and motion. Confirmation of the rates and direction of plate motion, which will take many years, will increase understanding of how and why earthquakes occur.

NASA's activities are well coordinated with other federal agencies such as the National Science Foundation (NSF), National Geodetic Survey, U.S. Geological Survey, and the Defense Mapping Agency. On the international scene NASA is engaging in talks with scientists of many other countries; project agreements with Japan and Australia are being negotiated.

In a related activity NASA, in cooperation with the NSF, explored the possible use of NASA large-

scale testing facilities for research in earthquake structures and geotechnical engineering. A NSF workshop held in 1979 concluded that several NASA test facilities could be used for these purposes and that some of the facilities, particularly for full-scale testing of buildings, are unique in the world. Planning is underway to make these facilities available for NSF-sponsored research.

Materials Processing in Space

NASA is developing capabilities in the space environment for materials research and processing applications, so as to demonstrate these capabilities to the scientific and industrial communities and to provide opportunities for independently funded users to exploit the space environment for materials processing applications related to their own needs. NASA has encouraged industry's early participation in the development of materials processing technology to ensure that the program reflects industrial needs.

To achieve these objectives, NASA is establishing a research base for materials processing technology, both to explore the effects of gravity on processes and to allow extensions of current capabilities into the environment of space. A range of opportunities and hardware will be made available to the scientific and industrial communities.

NASA has been working with an advisory committee of distinguished materials scientists, including members of the National Academy of Sciences, to develop new approaches for materials processing in space. The main feature of the new orientation is a considerably increased emphasis on ground-based research. As this emphasis has been made known, there has been a substantial rise in the number and quality of research proposals submitted and a noticeable increase in materials scientists' willingness to participate in activities related to materials processing in space. Both trends reflect the scientific community's increasing confidence in the utility of studying and performing materials processing in the space environment.

Interest has also been fueled by new research results showing that the force of gravity has important influences on some processes and that significant new knowledge can be obtained on these processes by experiments in weightlessness.

Fundamental studies of the interference with fluid behavior by gravity-driven convection have been performed. For example, basic differences in the freezing of materials have been observed by carefully controlling the orientation of the experiments in Earth gravity or by using the low gravity environment of sounding rockets. Casting structures produced in low gravity are fundamentally different

because of the reduction in thermal convection flows. It will now be possible to design schemes for controlling casting structures through the reduction or enhancement of convection. The detailed nature of such interactions is being explored for many different materials processing systems, involving extremely subtle and little understood phenomena in both heat- and mass-transfer effects. The solidification process for complex alloys, for example, has been found to possess unstable time-dependent effects that cannot be avoided in one-g. Avoidance of such convection effects—as in zero-g—is absolutely essential if controlled materials structures and related properties are to be produced.

NASA has made substantial progress this past year in the area of containerless processing. The ability to study and prepare materials in the absence of solid containers has stimulated interest in the mechanisms by which solids can be formed from liquids under very high cooling rates. Space conditions could mean the diffusionless transformation of molten liquids to solids; these solids would have substantially higher compositional uniformity and thus enhanced performance in extended operating conditions. Applications of such materials include jet-engine turbine blades or nuclear-reactor rod sheaths. Interest has also been expressed in the ability to measure the properties of molten substances at extremely high temperatures where solid containers do not exist. These properties are of interest in such applications as the fabrication of nuclear-reactor rod sheaths, nuclear reactor core design, and magnetohydrodynamic power generation.

Containerless processing plays a vital role in fusion power being investigated by the Department of Energy as a possible new source of energy. One approach is laser bombardment of a deuterium-tritium fuel mixture contained in precise ultra-thin-wall glass microsphere shells. The shells must be perfect spheres with walls of uniform thickness. Those in use today are made by dropping particles of glass-forming materials through a high-temperature vertical-tube furnace where size is limited to a few tenths of a millimeter in diameter at most. Shells ten times as large, or larger, are needed.

During the past year NASA has been studying fundamental processes involved in glass-shell formation and investigating the possibility of making larger shells. Theoretical work at the Jet Propulsion Laboratory (JPL) has shown that large shells can be made in free fall where the surface tension of the molten glass can hold it in a highly spherical shape. Experiments in zero-gravity aircraft flights have demonstrated that oscillations of a spherical shell tend to make its wall thickness more uniform. Close cooperation has been established between JPL and DOE's Lawrence Livermore Laboratory.

The Space Processing Applications Rocket (SPAR) experiments continued to provide information valuable to the understanding of materials processing in space. Two Spar V experiments on the freezing of ammonium chloride solutions simulated the behavior of dendrites in metal casting. In one experiment, bidirectional freezing formed no dendrite fragments; thus the freezing structure consisted completely of aligned dendrites with no zone of random orientation normally found in earth castings. Knowledge from such experiments is fundamental in controlling the formation of composite materials. Spar VI was launched in October 1979, and its data are being analyzed.

Technology Transfer

Technology transfer continues to play a major role in NASA's efforts to broaden the base of technology applications transfer begun in the R&D programs.

Emphasis in space applications remains in remote sensing, where user interest in operational systems is growing into action, particularly at the state government level. Under a continuing cooperative project, the National Conference of State Legislatures (NCSL) has been responsible for legislative hearings on Landsat in eight states over the past year and has supported NASA in two Executive Agency workshops. Over 5000 copies of the Conference's "Legislators' Guide to Landsat" have been distributed to state governments, industry, and universities. NCSL's Natural Resources Information System Task Force has been a major source of state "feedback" to the Administration and the Congress on state interest and needs regarding Landsat—both through formal recommendation and through testimony before the Congress. NCSL is also assisting NASA to understand how states could use Landsat data through analysis of state implementation of natural resources legislation.

The parallel liaison effort with the National Governors' Association (NGA) is now fully operational. An Earth Resources Data Council creates an effective forum for communicating with and representing state interests in operational systems development for remote sensing. The Council has, on request, provided state perspectives on open issues in the Landsat-D program and a Federal multi-agency study on classification and inventories of natural resources, as well as commenting on Administration studies of options for operational systems. Both NGA and NCSL representatives testified during Senate hearings this summer, giving state views on an operational Landsat system.

Specific technology transfer programs with state governments are carried out principally through the

three NASA Regional Centers. All three have newsletters to keep users informed on state activities, related NASA programs, and technology developments.

A number of major analysis programs have now been documented and made public and more are on the way. Analysis software is also being adapted to run on a variety of computer systems and analysis software has been installed on a national time sharing computer network (COMNET) to provide easy, low cost, interim access to analysis capabilities for users still in the exploratory stage. Listings and technical summaries of commercially available analysis software and geobased information systems have been published to help users find assistance in the private sector.

Through the Applications Systems Verification and Transfer (ASVT) program, emerging applications technology is being verified and transferred to a variety of users. Users involved in the seven current ASVT programs include eight federal agencies, thirteen states, and two regional commissions.

NASA's Ames Research Center is concluding an extensive ASVT project with the Pacific Northwest Regional Commission and state agencies in Washington, Oregon, and Idaho to develop operational Landsat analysis capability. During FY 1979, the states and the Regional Commission assumed major financial responsibility for the continuing effort. NASA will provide some continuing phase-over support, principally involving software and training. For example, Landsat data processing software is now operating on computers at Washington State University and the State Auditor's computing facilities in Idaho. The states have assumed complete responsibility for the Landsat data application projects. A self-sustaining Landsat processing and analysis capability is projected in these states in FY 1982.

While the AVST programs are quite effectively meeting a number of important immediate needs, the key to future growth is building a strong technical base in the user community. Toward this end, the University Applications Program has developed remote sensing centers at universities in 25 states. To broaden these benefits each year, one or two programs are phased out and moved to other universities in other states. Over the past few years, NASA support has been phased out at seven of these schools but, as planned, the remote sensing centers continue to be viable with funding from other sources. In other words, they have become self-supporting institutions for research, education, and expertise for problem solving—a continuing resource for the university and the state.

University applications are not limited to remote sensing applications. In line with NASA policy and

an implementation plan approved this past year, NASA began to expand and strengthen the involvement of the academic community in applications programs by devoting a larger fraction of resources to basic research. Today the major barriers to progress in many areas, including climate prediction, weather forecasting, agricultural productivity assessment, and location of mineral resources on the Earth's surface, stem largely from lack of basic knowledge about many of the geophysical, geochemical, and biological processes. Only strong activity in basic research can provide the insight for design and development of an effective space observations program.

Under the new program, universities will be funded to do independent basic research where the long-term objectives would be in consonance with those of the program, but not necessarily directly related to a specific space mission. The first program was started in FY 1979 in geodynamics, focusing on the nature of the mechanisms that drive the tectonic plates and the way the plates deform in response to the driving forces.

Science

Space science aims at an understanding of the origin and continuing evolution of the cosmic environment; the origin and evolution of the solar system; the origin and distribution of life in the universe; and the dynamic processes that shape the terrestrial environment. Space science also uses space technology and environment to further knowledge in medicine and biology.

Study of the Sun and its Earth Effects

As our ultimate source of light and heat, the Sun has profound effects on all parts of the Earth's environment. NASA studies the Sun, the solar wind, the Earth's magnetosphere and ionosphere, and the complex interactions between these elements.

Skylab Data Analysis. Fiscal Year 1979 was the final year of sustained postflight analysis of data for the Skylab experiment teams. During their relatively brief nine-month period of operation (1973–1974), the instruments of Skylab's Apollo Telescope Mount revolutionized our perception of the Sun. The observations of the forms and evolution of coronal holes and their identification with high-speed solar wind streams, the observation of large numbers of coronal transient events and their connections with underlying activity on the solar surface, and the observations that the hottest parts of solar flares occur within very compact magnetic arches are only a few of the major breakthroughs derived from this

mission. The current cumulative total of ATM publications is 359, plus three book-length monographs from Skylab workshops.

International Sun-Earth Explorer. The International Sun-Earth Explorer (ISEE) program involves three spacecraft, and is a collaboration with the European Space Agency (ESA). ISEE 1 and 2 are in highly elliptical orbits, one following the other closely as they pass through different regions of the Earth's magnetosphere. On November 20, 1978, ISEE 3 was injected into a "halo" orbit about the Earth-Sun libration point, which is about 1.6 million kilometers from Earth (0.01 AU) on the Earth-Sun line, from which point the solar wind can be observed an hour before it reaches the Earth's magnetosphere. This capability is useful for advance warning of impending magnetospheric and ionospheric disturbances near Earth, which the ISEE 1 and 2 spacecraft then monitor. In addition, ISEE 3 has seen a surprising number of particles streaming away from the Earth toward the Sun. These probably originate from the solar wind, and are reversed by a mechanism not yet understood. A similar phenomenon has been observed near Jupiter. Such magnetospheric acceleration suggests a way in which low-energy cosmic rays may be produced.

Project CAMEO. In Project CAMEO (Chemically Active Material Ejected in Orbit), canisters containing barium and lithium were carried on the Delta vehicle that launched Nimbus 7. On October 29, 1978, four barium canisters were released by telecommand at 40-second intervals. The barium initially streaked upwards at speeds and to altitudes that indicated that electric fields must have been present. This result provided direct evidence for one of the acceleration mechanisms suspected from ISEE and earlier data. Plasma instabilities then broke the streaks up into striations, an effect not seen from rocket releases with lower injection velocities. Lithium was released a few days later and detected with sensitive photometers in Scandinavia and by atmospheric laser probing from France.

Solar Maximum Mission. Solar activity has been increasing rapidly, and the evidence indicates that the sunspot maximum for this solar cycle will be high and should occur early in 1980. This maximum period is ideal for the Solar Maximum Mission (SMM) to observe active regions and flares, since the SMM is now scheduled for launch in early 1980. The slip from the original October 1979 launch date was caused by minor technical problems, and by a need to fully develop the complex ground control and data handling facilities. The experiments were integrated with the SMM spacecraft, subjected to final environmental tests, and shipped to the Kennedy Space Center in January 1980. The Investigators Working Group met a number of times

and developed a large array of sequences for coordinated observations of solar phenomena by all of the SMM experiments.

International Solar Polar Mission. The International Solar Polar Mission (ISPM) will be the first space mission to explore interplanetary and solar phenomena from the plane of the solar equator to above the solar poles themselves. Two spacecraft—one European and one American—are expected to be launched by the Shuttle in 1985; they will be boosted by an Inertial Upper Stage (IUS) to Jupiter, and will use gravitational swing-bys for acceleration out of the ecliptic plane, with passage over the poles of the Sun in 1988. The ISPM is a cooperative mission with the European Space Agency (ESA), under a Memorandum of Understanding signed in March 1979. Science approval of investigations was also completed in March 1979, and all United States investigators are currently under contract for experiment development. The prime contractor for the United States spacecraft was selected in July 1979.

Reusable Facilities for Solar Research. The selection of the first set of solar terrestrial instruments for follow-on Spacelab missions was completed in August 1979. Two multiuser instruments will be developed: the solar optical telescope and the chemical release module. The telescope will be a 1.25-meter diffraction-limited model with a variety of focal-plane spectrographs and imaging instruments. It will offer a ten-fold improvement in our ability to resolve fine detail on the Sun's surface compared to that routinely possible with ground-based telescopes. The solar physics experiments will complement the telescope's temperature coverage in the solar atmosphere. These experiments include an extreme ultraviolet spectrograph, an imaging x-ray telescope and spectrometer, a white-light coronagraph, and a coronagraph designed to measure coronal temperatures and densities through observations of scattered radiation from hydrogen atoms and O^{+5} ions.

The chemical release module will inject small amounts of tracer elements into the Earth's magnetosphere to map mass motions and electric fields and to investigate ion acceleration processes. The tracers will be observed with sensitive TV systems on Spacelab and on the ground, with mass spectrometer systems on Spacelab, and with a remote spectroscopic observatory on Spacelab. All the space plasma physics investigations will emphasize active experiments from Spacelab—injecting particles or waves into the magnetosphere and ionosphere and then observing the effects of these injections at varying distances from Spacelab.

Study of the Planets

The United States planetary exploration program made remarkable advances in several areas in 1979. Large quantities of new data have been returned by unmanned spacecraft visiting Venus, Jupiter, and Saturn. A first look has been taken at the four large Galilean (Jupiter) moons—moons big enough to be important objects in the newly emerging science of comparative planetology. The data returned from the various spacecraft span a wide range of disciplines; the quality and quantity of those data have increased immeasurably since the beginning of planetary exploration almost two decades ago.

Pioneer Venus. The Pioneer Venus multiprobe spacecraft and orbiter arrived at Venus toward the end of 1978. During 1979, over 100 scientists have worked both to analyze the data returned by the probes during their brief descent through the atmosphere and to continue the operation of the orbiter which has now passed into a second Venusian year. The *in situ* probe measurements have provided basic information about the nature of the Venusian atmosphere. Of great interest are the quantities of rare gases which are present in trace amounts: these gases do not enter into chemical compounds and can therefore provide relatively direct information about the nature of the original materials from which the planets formed. Although the results are still subject to considerable uncertainties, comparisons with direct measurements of the Earth's and Mars' atmospheres (the latter made by Viking) show that the proportion of such rare gases, relative to the total planetary mass, decreases in order-of-magnitude steps from Venus to Earth to Mars. The reason for such a circumstance is as yet unclear, but in time this information may lead to important insights into the nature of the primitive solar system.

Large concentrations of sulfur compounds were measured in the lower atmosphere of Venus; it is clear that sulfur is an important ingredient of the pervasive Venusian clouds, apparently composed in part of sulfuric acid. Challenging problems remain in understanding the sulfur chemistry of the lower atmosphere and the clouds; these problems will be the subject of future data analysis and synthesis.

Pioneer Venus, through its radar altimeter, has added significantly to our meager knowledge of the planet's surface. A broad plateau has been identified; about 1000 kilometers across, it rises about 6 kilometers above the surrounding plain. Comparable topographic features are found on Earth, but not on the other inner planets. Its origin seems associated with large-scale crustal forces.

Much of the data analysis presently under way is involved with the many Pioneer Venus investigations

of the static and dynamic characteristics of the atmosphere and its complex cloud layers. The data are so extensive and the results so promising that analyses will continue for several years. The Soviet Union also sent probes to Venus in late 1978. The two nations are exchanging data and engaging in joint analyses, which will increase the value of each nation's mission.

Viking. The active presence of United States spacecraft at Mars continues, almost four years after the arrival of Viking at Mars. At the end of 1979, one orbiter still had a supply of attitude control gas and was returning high-resolution imagery. The two landers returned imaging, meteorology, and radio science data during the year. The more equatorially located of the two landers has been programmed to allow periodic interrogation of the spacecraft for the next decade. A substantial analysis team continues to study the several years' worth of data returned by the landers and the orbiters.

Voyager 1 and 2. The two Voyager passages through the Jupiter system were a fitting close to a decade of United States planetary exploration that brought new understanding of how the solar system was formed and in what ways the histories of the planets were similar or different. Like the inner planets—Mercury, Venus, and Mars—Jupiter had been examined by spacecraft before. The Voyager missions benefited from the earlier experience of Pioneer 10 and 11; they also gained capability from major improvements in the technological state of the art, both in spacecraft instrumentation and in ground receiving equipment—a system improvement, *Science* magazine asserted, “a factor of 150,000 times better than that used with the 1965 Mariner mission to Mars.”

Voyager 1, launched September 5, 1977, began measuring the Jovian system on January 6, 1979. Its closest approach to Jupiter was 348,890 kilometers on March 5. During the 98-day period before and after closest approach, the spacecraft returned more than 18,000 images of Jupiter and its four Galilean planets, as well as mapping the accessible portion of Jupiter's complex magnetosphere. In Jupiter's atmosphere, some significant observations were: a belt-zone pattern of east-west winds near the poles, where it previously was thought that the weather systems were driven by convection (upwelling and downwelling); much interaction around the fringes of the Great Red Spot—the massive storm that has been prominent for at least 400 years—including anticyclonic motion of material, the impinging of smaller spots on the edges of the Great Red Spot and on each other, and substantially colder atmosphere above the Great Red Spot; massive cloud-top lighting bolts; auroral emissions in

the polar region in both ultraviolet and visible wavelengths; and uniform velocities of atmospheric forms quite different in scale, arguing that mass motion rather than wave motion is being observed. In the diverse satellites of Jupiter: 7 active volcanoes on Io, with plumes reaching 250 kilometers above the surface; a heavily cratered, ancient crust on Callisto, with ring remnants marking huge impact basins since filled in by flow of the icy crust; on Ganymede, both grooved and cratered terrain, possibly from global tectonic stresses; on Europa, a surface crisscrossed with linear marks, possibly from tectonics or crustal lifting; and a planetary ring around Jupiter, beginning some 100,000 kilometers out from the center of the planet and measuring some 30 kilometers thick. In the magnetosphere: well defined bow shock wave and magnetospheric boundaries and tail, similar to Earth; existence of a 5-million-ampere magnetic flux tube between Jupiter and Io.

Voyager 2, launched 16 days earlier than Voyager 1 but arriving at Jupiter four months later, passed closest to Jupiter on July 9. Its 13,000 images naturally showed fewer discoveries than those of Voyager 1, but did much to supplement and amplify them. Among its valuable coverages were: four-month-later patterns of Jupiter's atmosphere, showing kinds and rates of change of structure; high-resolution views of volcanoes erupting on Io and additional views of the other Galilean satellites; and clearer pictures of Jupiter's ring, showing it to be more extensive and possibly more complex than it seemed on Voyager 1 imagery.

Safely past Jupiter, the two Voyager spacecraft used the planet's gravity to bend their course across the solar system toward the second largest planet, Saturn. Voyager 1 is to arrive at Saturn in November 1980, Voyager 2 in August 1981. If fuel remains, Voyager 2 may venture on to Uranus by 1986.

Pioneer 10 and 11. During the year Pioneer 10 traveled another 410 million kilometers on its way out of the solar system. It continues to return basic information about the charged particles and electromagnetic fields of interplanetary space in the region where the Sun's influence is fading. Pioneer 11, moving in the opposite direction to its sister ship, completed the first spacecraft journey to Saturn in September 1979. Though a relatively simple spacecraft in comparison to Voyager, Pioneer 11 returned data that have added significantly to our understanding of the most vividly ringed planet in the solar system. The spacecraft measured the strong magnetic field of Saturn and confirmed that the planet is radiating more heat than it receives from the Sun. It discovered a new faint ring outside those famous ones visible from Earth. Information

about the temperature and mass of the rings acquired on this flight will significantly constrain the range of possible explanations for the nature of these striking phenomena. While Pioneer 11 did not penetrate the rings, it did come close enough to demonstrate the safety of the environment just outside the rings. This is important for Voyager 2, which must pass through the same region if it is to continue on to Uranus after its Saturn encounter. It found that since the rings almost totally absorb the energetic particles trapped by the magnetic field, there is a benign radiation environment beneath and above the rings.

Saturn's large moon, Titan, was also observed and its temperature measured. Though this large moon is especially tantalizing because of its significant atmosphere, Pioneer flew no closer to it than 356,000 kilometers, so it remains a highly enigmatic object.

Both Pioneer 10 and 11 will be tracked and interrogated for several more years; no more planetary encounters will occur, but the spacecraft will be reporting from unexplored regions of space.

Research and Analysis. Work continued on the interpretation of data sent back from previous missions, such as Viking, and on acquiring new information about the solar system by means of ground-based telescopes. A highlight of the year was the completion of the Infrared Telescope Facility on the summit of Mauna Kea in Hawaii, the best observing site in the world. Many unique features provide the new telescope with exceptional performance in collecting key information about planetary bodies by observing the thermal emissions of their surfaces and atmospheres. The new telescope supported the Voyager 2 encounter with Jupiter and will be important for the success of the Voyager encounters with Saturn and for the Galileo mission. All the planets will be studied; at times when planetary objects are in unsuitable positions for study, the telescope will be operated as a nationally available facility for stellar astronomy.

Studies of the Universe

The NASA program in astrophysics is directed toward answering some of the most fundamental questions that mankind has ever posed—what is the nature and origin of the universe? How will it end? What is the origin of the elements of which the Earth and our bodies are constructed? What is the nature of exotic high energy physics occurring in space?

High Energy Astronomy Observatories. After a highly successful operational lifetime of nearly one and one-half years, HEAO 1 reentered the atmo-

sphere in March 1979. HEAO 2 was launched in November 1978, and is continuing to function well. Both observatories have added diverse and complementary data on a wide variety of x-ray emitting objects.

With regard to observations of stars, HEAO 1 established that the class of stars known as RS CVn stars exhibit relatively strong x-ray emission, which presumably arises in the very hot, active atmospheres, or coronae, of these stars. HEAO 2 confirmed this result, and further demonstrated that a considerably wider class of stars, ranging from very massive, hot, young stars through less massive, cooler, evolved stars (some very similar to the Sun) are unexpectedly bright x-ray sources. These discoveries indicate that earlier theories of stellar atmospheres must be discarded or seriously revised. HEAO 2 has provided the basis for a better understanding of the structure and generation of stellar atmospheres.

HEAO data on supernova such as the Crab Nebula indicate the presence of heavy elements, in roughly the same abundances as in the solar system, in the expanding shell ejected during the initial supernova explosion. Interestingly most of the observed supernova remnants do not contain an observable compact object as expected. This implies either that the compact object is not a conventional neutron star, or that a compact star was not produced by the explosion at all. In either case, a revision of theory of the origin of neutron stars, their structure, and the supernova phenomenon is clearly required. Studies of the x-ray pulses and erratic fluctuation of the x-ray binaries are in progress, with the potential of detailing the internal structure of neutron stars and providing increased evidence for the existence of black holes.

HEAO 1 and 2 have also provided data on the vast scale of the universe itself. In particular, the nature of the diffuse x-ray background has a direct bearing on the ultimate fate of the universe. If this background radiation is caused by a very hot, diffuse gas distributed uniformly through space, this could provide enough mass to "close" the universe. Alternatively, if the background arises from a large number of discrete x-ray sources, there would be insufficient mass to halt the expansion and the universe would expand forever. The data, from HEAO 1 and 2 give different answers to the questions. At present, it is fair to say that a large fraction of the low energy x-ray background seen by HEAO 2 is composed of distant, discrete sources, while some fraction of the high energy x-ray component observable by HEAO 1 is truly diffuse.

HEAO 3 was launched from Cape Canaveral by an Atlas-Centaur launch vehicle into near-perfect orbit on September 20, 1979. The observatory car-

ries three instruments to study gamma ray emissions and cosmic-ray flux in the universe. The cryogenically cooled gamma-ray spectrometer, supplied by the Jet Propulsion Laboratory, is receiving excellent data on gamma-ray source location and nuclear line emissions. A cosmic-ray instrument, investigating isotopic composition and supplied by a consortium of French and Danish scientists, is operating well. The third instrument, supplied by three American universities (Washington University, University of Minnesota, and the California Institute of Technology) is designed to study heavy nuclei in space and is performing very well.

Space Telescope (ST). The design and development of the ST is progressing on schedule and within budget toward a December 1983 launch by the Space Shuttle. With its 2.4-meter (96-inch) primary mirror, the ST will be able to view celestial objects 50 times fainter than large Earth-based telescopes can and with a resolution improvement of a factor of 10.

The ST will have a long lifetime—of more than a decade. This is made possible by the Space Shuttle providing on-orbit repair, exchange of scientific instruments, or return of the entire observatory to Earth for refurbishment and subsequent relaunch.

Preliminary design reviews for the three major components of the ST (the support systems module, the optical telescope assembly, and the scientific instruments) were completed early in 1979, and the scientific payload was confirmed. Grinding and shaping of the two primary telescope mirror blanks were finished during the past year. In 1980 the design phase of development for all components will be completed and fabrication and assembly of the scientific instruments and the optical telescope assembly will begin.

A new institute will be established to conduct the integrated science program of the ST, including selection and support of telescope observers, science planning and scheduling, and data analysis. The request for proposals for management and operation of the ST science institute was released in late 1979; contract award is planned for late 1980.

Explorer Satellites. Explorer satellites carry relatively low-cost payloads designed to explore new fields of scientific research. The International Ultraviolet Explorer (IUE), launched on January 26, 1978, into an eccentric geosynchronous orbit, is still operating well. The program is a joint undertaking by NASA, the United Kingdom's Science Research Council, and the European Space Agency (ESA). The IUE provides the capability to study the spectral lines associated with the transmission and absorption of atomic radiation in the atmosphere of stars and in the innerstellar medium, as well as with objects within the solar system. The IUE

has demonstrated the ubiquitous nature of stellar winds, which represent substantial mass loss for all types of stars and significantly affect their evolutionary paths. It has produced the first evidence confirming the existence of a galactic halo, consisting of high-temperature, rarified gas extending far above and below the plane of the Milky Way. Further, it has proved useful in the study of flare stars, which undergo eruptions many times more violent than have ever been observed on the Sun.

The first observations with this satellite generated such excitement that over 180 proposals have already been received for observing time on IUE during 1980, although only 120 observing programs can be accommodated.

Another international Explorer, the Infrared Astronomical Satellite (IRAS), is the first satellite designed to study the cold infrared universe. This cooperative project with the Netherlands and the United Kingdom is scheduled to place a "first of its kind" cryogenically cooled telescope system in orbit in 1981. The primary mission is to produce an unbiased all-sky survey of discrete sources to identify the location and variety of objects radiating in the infrared. The telescope system is to be furnished by the United States and to be managed by the Jet Propulsion Laboratory and the Ames Research Center. The detectors for the telescope's focal plane were selected in September 1978.

Development activity is proceeding on four other Explorer projects. The Dynamics Explorer, which will investigate the interactions between the Earth's magnetosphere and ionosphere, is in final development, leading to launch in 1981. Development work continues on the Solar Mesospheric Explorer. Also to be launched in 1981, it will determine solar ultraviolet flux and study changes occurring in ozone and related chemistry as a result of that ozone radiation. Development work continues on the Cosmic Ray Isotope Experiment to be launched on a DoD satellite in 1981 and again on the San Marco-D missions, a cooperative project with Italy having launches in 1981 and 1982.

Detailed study continues on three future Explorers. One is a joint NASA-German Federal Ministry for Research and Technology mission, the Active Magnetospheric Particle Tracer Explorer. NASA will provide the Charge Composition Explorer, Germany the Ion Release Module. The Cosmic Background Explorer will measure the residual three-degree-Kelvin background radiation believed to be associated with the "big bang" origin of the universe. The Extreme Ultraviolet Explorer will survey the sky for very hot objects such as white dwarfs, opening up one of the few remaining unexplored regions of the electromagnetic spectrum.

Orbiting Astronomical Observatories (OAO). OAO-3, named Copernicus, is still operating successfully more than seven years after launch. It continues to furnish valuable information on an apparent black hole detected in the constellation Scorpius.

Suborbital Vehicles. Sounding rockets, balloons, and aircraft continue to make their contributions to technology and science. For example, in the NASA balloon program, a far-infrared telescope has measured the contribution that dust in our Milky Way galaxy makes to the total luminosity of our galaxy, giving information on the rate at which stars form throughout our own galaxy.

In the NASA airborne program, instruments aboard the Kuiper Airborne Observatory have detected, for the first time, a far-infrared molecular line from carbon monoxide in a region where stars are forming. Since the cooling of this region is caused mainly by carbon monoxide, and since most of the radiation is coming out in the form of these lines, measurement of their intensities plays an important role in understanding the energy balance of star-forming regions.

The sounding rocket program became linked to scientific use of the Shuttle in 1979 when approval was given for a development test flight in 1981-1982 to demonstrate the concept of flying sounding rocket payloads off the Shuttle in a 24-hour free-flyer mode, then to be recovered and returned by the Shuttle. The concept is a logical extension of the sounding rocket program with the added capability of obtaining 24 hours of scientific data as opposed to the 10 minutes from a sounding rocket flight.

Astrophysics Spacelab Payloads. A significant milestone has been reached with regard to scientific use of the Shuttle. Ten instruments for high-energy astrophysics and astronomy have been selected for development and flight on fully operational Shuttle Spacelab missions starting in 1983. These ten, plus approved reflights of two Spacelab 2 instruments and six new instruments approved for study, represent an intensive selection process that originally started with a total of 94 proposals.

Life Sciences

The life sciences program concerns itself with the physiology of man in space and more generally with living or life-like processes in space, whether of terrestrial or extraterrestrial origin.

Medical Operations. Measures to maintain the health and safety of Space Shuttle crew members have continued to be of prime concern. To mitigate any adverse effects of returning these crew members to Earth's gravity, tests have been conducted with

anti-g suits that can be inflated automatically during reentry when the flow of blood to the head is diminished. Other more sophisticated procedures employing water-cooled suits and blood volume replenishment have also been developed for longer missions and more susceptible non-astronaut passengers. The prospect of some crew members encountering motion sickness has necessitated a comprehensive drug screening program to select those medications that will be most effective and will have the least side effects. Several drug combinations used on both men and women have been found to have these desirable characteristics. Better methods of administering the drugs have also been studied; a procedure that permits the drug to be absorbed through the skin appears to be most promising.

Biomedical Research. Several laboratories have participated in a concerted effort to understand more about the structure and function of the human vestibular apparatus and its neural interconnections. Using experimental animals, key anatomical fiber tracts have been located. Techniques for pinpointing the involvement of specific parts of the nervous system in the genesis of motion sickness have been developed, and experiments have been defined for employing these techniques in the Shuttle and Spacelab.

Substantial improvements have been made in the instrumentation and procedures for detecting of bone deterioration. These procedures, based on computer-aided tomography, have demonstrated subtle structural changes in the bones of human test subjects confined to bed. Similar changes are believed to occur in spaceflight. Experiments are being prepared for applying the new technology to Shuttle crew members. With bedrest as an analogue of space flight, a diphosphonate-containing drug, capable of partially protecting the integrity of the bones, has been successfully tested. Several flight experiments have been selected to elucidate the mechanisms underlying the loss of bone mass in space. Some of these will be flown on Shuttle/Spacelab, while others are taking advantage of flight opportunities offered to the United States in the Soviet Cosmos biosatellite program.

Cooperative efforts with the Soviet Union have included both the flight of United States biological experiments on unmanned Soviet spacecraft. In 1979, the third such Soviet biosatellite carried 14 United States experiments. Cooperation in this area also includes joint ground-based clinical studies. Although the 1979 study has emphasized validation of a more authentic experimental model for the effects of weightlessness of the human cardiovascular system, an additional dividend has been the standardization of test procedures applied to American astronauts and Soviet cosmonauts. In Moscow, dur-

ing the month of May, and again at NASA's Ames Research Center in August, ten subjects were studied intensively for five weeks by teams of Soviet and American investigators. The data obtained were reasonably similar despite the geographic separation of the test centers and the diversity of investigators and experimental subjects.

Space Biology. A study of the effect of gravity and other physical forces on the growth and development of plants has pointed to the importance of the hormone ethylene in these processes. Mechanical stress accelerates production of this compound, which in turn causes dwarfing and the failure of the plant's gravity sensing. Studies of the relationship of gravity to a broad spectrum of other biological processes has enabled refinement of an animal model system simulating certain aspects of weightlessness. The changes in a rat suspended with the longitudinal axis of its body pointed head-down have faithfully mimicked many of the metabolic and structural changes that occur in the absence of gravity.

Exobiology. Research in planetary biology is focused on the origin, evolution, and distribution of life-related molecules on Earth and elsewhere. A new line of investigation this year emphasizes attempts to decipher the long series of evolutionary events that characterized early biological history.

Recent discoveries from laboratory simulation, modeling, and ground-based observations all indicate that comets may represent a unique reservoir of information regarding precursors to life at the time of the formation of the solar system. In addition to providing further support for theories that chemical evolution occurs in locations beyond the Earth, these findings have led to the theory that comets may, in fact, have played a major role in organic chemical evolution on the primitive Earth. Calculations have shown that significant amounts of important early forms of molecules could have been deposited on the planet Earth during its earliest history by falling comets.

Simulation experiments have successfully duplicated data from one of the more controversial life detection experiments on the Viking Mars landers. Specially prepared clays, when mixed with salts in amounts consistent with other Viking measurements, catalyzed the release of carbon dioxide in a fashion similar to that observed in the Viking labeled-release experiment. Recently it has been shown that these same clay-salt mixtures can be inactivated by heating at 160°C for 3 hours. The sensitivity to heat observed in the labeled release experiment was the most biological-like response observed on Mars and the most difficult to simulate on Earth.

Flight Program. The Shuttle/Spacelab life sciences flight experiments program will provide ob-

jective, quantifiable research data that will give NASA and the scientific community answers to the many problems raised in the Skylab programs. The most immediate problem is space motion sickness, which impaired the ability of the astronauts to perform in the early hours of their exposure to space. This nausea affected about half of the astronauts for from one to four days. With the early Space Transportation System flights scheduled to last 7 to 10 days, the STS crew and payload scientists could, if similarly affected, lose a substantial amount of productive time because of this discomfort. Additional problems concern fluid and electrolyte balance, sensory deprivation, diurnal rhythm changes, cardiovascular deconditioning, circulation impairment, and muscle atrophy.

Life Sciences experiments for Spacelab 1, 2, and 3 are in the hardware phase. During the past year, over 370 proposals for Life Sciences flight experiments onboard a dedicated mission were reviewed and evaluated by 13 panels of non-NASA scientific peers. NASA analyzed the proposals for engineering, cost, and mission compatibility considerations. Ninety proposals were identified as scientifically and technically sound investigations and candidates for flight experimentation. The majority of these investigations are being funded for an experiment definition phase, after which the field will be further narrowed to 50–60 investigations. From this group, payloads for two dedicated missions will be selected.

Spacelab Payloads

During 1979, responsibility for the planning, development, and operation of all NASA Spacelab missions was consolidated into the new Spacelab Mission Integration Division within the Office of Space Science (OSS). Comprised of functions and elements from both Space Science and the Office of Space and Terrestrial Applications (OSTA), this division will provide a single focus for NASA Spacelab mission management. Responsibility for planning and developing the NASA Spacelab payloads or instruments themselves will remain in the discipline divisions of the program offices. In addition to refining these management arrangements, other steps have been taken to prepare for Spacelab operations. In late 1978 the physical integration of instruments or experiments into Spacelab hardware was assigned to the Kennedy Space Center (KSC). During 1979, progress was made in arranging for contractor support for that activity. In September, a draft statement of work for such a contract was circulated to industry for comment. The comments received will help NASA to better integrate the re-

quirements and capabilities involved in this complex area.

The payload development has been progressing satisfactorily. In late 1979, the instruments that will be flown on the first Shuttle payload missions were delivered for integration into Spacelab pallets. The first mission, OSTA 1, will carry instruments to be used in gathering Earth resource and environmental data that will help to deal with many problems in those areas. The Johnson Space Center has mission management responsibilities for OSTA 1. The other mission, OSS 1, is managed by the Goddard Space Flight Center. The instruments on that mission will gather solar physics data, evaluate the ambient and induced Shuttle space environment, and provide data on payload thermal control technology. Another experiment dealing with Life Sciences (plant growth research) will be located in the Shuttle cabin.

Significant progress was also made on the Spacelab missions 1 and 2, the first extensive operational demonstrations of the Spacelab hardware being furnished by the European Space Agency. During 1979, the Spacelab 1 and 2 missions moved into the final design phase and manufacture of flight hardware was begun. Final design and operations reviews have been held for all instruments and most investigators are well into fabrication of their flight hardware.

About 140 investigations were selected during 1979 for future Spacelab missions. As these activities mature, and as we gain a clearer insight into future requirements, Spacelab mission planning will focus on more effective and efficient use of Spacelab hardware and Space Transportation System capabilities.

Space Transportation

Space Shuttle

The Space Shuttle will be the first reusable Earth-to-orbit vehicle, meeting the needs of NASA, DoD, and other domestic and international users of space. It will provide efficient, economical access to space and will greatly enhance the flexibility and production of space missions, producing savings in the cost of space operations which cannot be achieved with today's expendable launch vehicle systems.

In the Space Shuttle development program, all major system elements are proceeding in test and manufacture, and major ground test programs are approaching completion. The design certification review of the overall Space Shuttle configuration was completed in April 1979. In general, development testing throughout the program has been completed

or soon will be, and the program is now deeply involved in the qualification of flight-configured elements.

Space Shuttle Orbiter. The orbiter vehicle will carry personnel and payloads to orbit, provide a space base for performing their assigned tasks, and return them to Earth. The orbiter's large cargo bay will be capable of carrying payloads weighing up to 29,500 kilograms (65,000 pounds) into space. The orbiter will provide a habitable environment for the crew and passengers, including scientists and engineers. The structural-test article for the orbiter is currently under subcontract for structural testing. This test article has a flightworthy airframe, and will be converted to become the second orbital vehicle, Challenger.

Work on the first flight orbiter, Columbia, proceeded at KSC at a slower pace than planned; much more work remains before the first flight, now scheduled in late 1980.

Main Engine. Three high-pressure hydrogen/oxygen main engines, each with a thrust of 2,000,000 newtons (470,000 pounds) are located in the orbiter's aft fuselage. The main engine represents a major advance in propulsion technology. It has a longer operating life, the ability to throttle the thrust level over a wide range, and is the first large, liquid-fuel rocket engine designed to be reusable. This highly advanced engine has experienced a number of development problems during its test program. Some difficulties still remain, but over 50,000 seconds of test time have already been accumulated toward the goal of 80,000 seconds before the first orbital flight.

External Tank. The external tank contains the propellants (liquid hydrogen and liquid oxygen) for the Space Shuttle main engines. Just prior to orbital insertion, the main engines cut off, and the external tank will separate from the orbiter and descend through a ballistic trajectory over a predesignated remote ocean area. The first flight tank has already been delivered, as have three test tanks. Three more flight tanks are being manufactured for flight in the orbital flight test program.

Solid Rocket Booster. Two solid-rocket boosters, attached to the external tank, will burn in parallel with the main engines to provide extra thrust during ascent. At completion of burn, the solid-rocket boosters will separate, descend on parachutes, and land in the ocean approximately 280 kilometers downrange, to be recovered and returned for refurbishment and reuse. Four development firings have been completed on this 3.7-meter-diameter booster, and the qualification firing program has been started. Two qualification motor firings have been made, and one more is scheduled before the

first flight. Most of the rocket segments for the first flight boosters have already been delivered to KSC.

Launch and Landing. All facilities at KSC are complete and in place for the first manned orbital flight. Although ground support equipment and the computerized launch-processing installations have been delayed, they are in the final stages of completion, and software validation is in process. All hardware for the launch processing system has been delivered, simulation support is continuing for development of checkout procedures, and checkout software is being developed and validated. Integration of all the ground support equipment will continue, and initial flight equipment is being checked out and processed for launch.

Follow-On Production. A national fleet of orbiters must be produced to meet the needs planned by the users of space for the 1980s. Following the test flights, the first operational Shuttle will be available in 1982 as an operational transportation capability for the many users of the Space Shuttle. Three additional orbiters will be delivered in later years, phased to accommodate increasing usage of the Space Transportation System. These additional orbiters (after Columbia) will be Challenger in 1982; Discoverer in 1983; and Atlantis, now scheduled for late 1984.

Operation of the Space Transportation System

When the Space Transportation System becomes operational in 1982, a greatly expanded range of space activities will be possible. A wide variety of users have already made firm commitments to use the system—civilian and military components of the United States government, and domestic and foreign customers, both governmental and private. They will be able to place a wide variety of payloads and experiments into Earth orbit. Payloads can be refurbished in orbit or returned to Earth for repair and relaunch; space laboratories can be launched, operated, and returned to Earth for examination; scientists can fly along to operate their experiments; geosynchronous or planetary missions will be possible with the aid of supplemental upper stages. With the art of the possible expanding so rapidly, and with flight hardware coming off the production line, NASA has placed major emphasis in 1979 on planning and preparing for operations.

Policies and Procedures. Policies on user charges during the early years of operations have been published in the *Federal Register*, describing the price structure and stipulating other conditions under which NASA will furnish launch services and flight hardware to government and commercial users. A reimbursement guide, which describes types and

costs of standard and optional services, is expected to be published in 1980.

Following extensive negotiations during the past year, nine commercial and foreign users, including Comsat, Western Union, RCA, Telesat/Canada, and the governments of India, Indonesia, and the Federal Republic of Germany have made payments or deposits on STS flight reservations. Together with NASA's own payloads, plus firm commitments for DoD and other United States government agencies, the first few years of STS operations are fully scheduled.

A program to provide for small, self-contained payloads was begun by NASA in 1977. Individuals, educational institutions, and industries can fly small payloads, requiring minimal support from the Shuttle, on a space-available basis at very reasonable prices. Both in the United States and abroad, this program has been extremely successful in attracting new users; by the end of 1979, advance payments had been received for more than 300 individual payloads, with a wide variety of ideas and experiments. The response from educational institutions has been particularly gratifying, since it indicates renewed interest from young people in space research and exploration. Several universities are offering science scholarships or grants for students to develop payloads.

DoD is developing STS launch and recovery facilities at Vandenberg AFB, California, to handle high-inclination missions. Maximum commonality of ground equipment at KSC and Vandenberg is reducing both acquisition and operating costs.

Flight Crew. The 35 astronaut candidates, including six women, selected in 1978 continued training at NASA's Johnson Space Center in Houston, Texas, and have been designated full-fledged astronauts in 1979. NASA has advertised for additional pilot and mission specialist candidates. Selections of candidates will be made in 1980. Policies for the selection, responsibilities, duties, and training of "payload specialist" and the scientific members of the crew were formulated in 1979 and published in the *Federal Register*.

Spacelab

Spacelab is an orbital laboratory being designed and developed by the European Space Agency to be carried in the cargo bay of the Shuttle. The major objective of the Spacelab is to provide access to space for a variety of experimenters from many nations and in fields such as material science, space processing, biology/medicine, meteorology, communication/navigation, and space technology.

The Spacelab offers the experimenters two options, a pressurized shirtsleeve laboratory (the

module) and an unpressurized platform exposed to the space environment (the pallet). It also offers the experimenters standardized support services. The Spacelab's normal mission lasts 7 days, although it can remain in orbit for up to 30 days. Design life expectancy is 50 flights of 7-day duration over a 10-year period. As many as four payload specialists can operate the experiments aboard the laboratory. The payload weights will range from 4800 to 8800 kilograms.

The 1973 agreement between the European Space Agency (ESA) and NASA calls for ESA to design, develop, and manufacture the first Spacelab flight unit and an engineering model, two sets of ground support equipment, and initial spares to support the first two missions. ESA's current cost-to-completion estimate is approximately \$800 million (FY 1979 dollars). NASA's responsibility is for operation of Spacelab; development of ancillary equipment, such as the tunnel between the Spacelab and the cabin of the Shuttle; development of the mission verification equipment; and procurement of one additional Spacelab unit from ESA.

In 1979, ESA delivered the second of two engineering model pallets to KSC. These payload-equipped pallets are scheduled to be flown on Space Shuttle orbital flight tests.

In Bremen, Germany, the prime contractor for Spacelab development continues to process the engineering model hardware. The initial flight unit is being assembled; testing is expected to start in 1980. Spacelab subsystem qualification tests are over 80 percent complete at various subcontractor facilities, with remaining tests scheduled for completion in 1980. Manufacturing and qualification testing of the engineering model pointing system are nearing completion.

The software to check out Spacelab on the ground and operate it in orbit is nearing completion. Preliminary issuance of this software has been delivered to NASA and is currently being used during integration and testing of the engineering model in Bremen.

NASA continues preparing for ground and flight operations for Spacelab flights. The critical design review for the verification equipment was completed. This equipment will be used to verify satisfactory performance of the first Spacelab module mission. The crew tunnel, which provides access to Spacelab from the orbiter, underwent a successful preliminary design review and a crew walk-through. The hardware for the software development facility was installed and checked out at MSFC. A critical design review for the experiment computer operating system was successfully completed. Installation of the crew training simula-

tor is in process at Johnson Space Center. NASA's resident office in Bremen, Germany, continues to monitor the integration and test activities on the engineering model and flight unit, at the same time learning how to prepare for technical support of Spacelab processing at KSC. It also monitors the acceptance and qualification testing of the engineering model and flight unit.

The Operations and Checkout (O&C) building is now operational at KSC and the first two Spacelab pallets to be used for orbital flight tests are being processed there for installation of payloads by the users. The Spacelab orbital flight pallets are scheduled to be turned over to the users this year.

In July, NASA and ESA concluded a follow-on procurement letter contract for the second Spacelab long-lead items. NASA also received ESA's total proposal for a second Spacelab and a contract with ESA was in preparation for signing early in 1980.

Upper Stages

Inertial Upper Stages. The Inertial Upper Stage (IUS) system is being designed and developed by DoD to extend the capability of the Space Shuttle into orbits beyond the capability of the Space Shuttle alone. The solid-propellant IUS and its payload are deployed from the orbiter in low Earth orbit; the IUS is then ignited to boost its payload to a higher energy orbit. NASA will use a two-stage configuration of the IUS primarily to achieve geosynchronous orbit and a three-stage version for planetary orbits. Full scale development continues with NASA coordinating the NASA-unique and other non-DoD requirements into the DoD IUS program to ensure its utility for other-than-DoD applications. The DoD's detailed design of the two-stage IUS configuration has been completed and subsystem hardware development is proceeding on a schedule that supports the first two-stage IUS launch of the tracking and Data Relay Satellite in 1982. Detailed design of the NASA three-stage configuration has been initiated.

Spinning Solid Upper Stages. Two sizes of Spinning Solid Upper Stages (SSUS) are being developed by American aerospace industries at their own expense for launch of smaller spacecraft to geosynchronous orbit. The SSUS-D is configured for satellites that have been using the Delta expendable launch vehicle, the SSUS-A for those using the Atlas-Centaur. SSUS designs have been completed and the qualification program initiated. Production is proceeding, with most flight hardware manufactured and ready for assembly. NASA has ordered SSUS-As for Comsat's Intelsat V communications satellite missions. NOAA's Geostationary Operational Environmental Satellite missions are now

planned for launch on SSUS-Ds, as are the launches of most commercial users, who are buying SSUS-Ds directly from the developer.

Skylab Reentry

Skylab, launched in May 1973, was the first United States orbiting laboratory. Operated by three successive crews for a total of 171 days, it was left dormant in February 1974, with an orbital life projected to about 1983. Sunspot activity had been greater than predicted, making the upper atmosphere more dense and accelerating Skylab's rate of orbital decay. Because of Skylab's large size, there was some concern of danger from its debris; a program to alter Skylab's orbit was approved for an early flight on the Space Shuttle of a teleoperator retrieval system. This program was reassessed in November 1978 and dropped because of its limited chance of success.

Skylab reentered and returned to Earth on July 11, 1979. Although some debris from the breakup landed in Australia, there were no reports of personal injury or property damage.

Advanced Programs

Studies and developments continued in 1979 to investigate concepts to improve the utility, flexibility, and effectiveness of the Space Transportation System, with special emphasis on the Shuttle orbiter. The definition and Shuttle interface studies were completed for the power extension package (PEP). PEP would provide the orbiter additional electrical power by means of a solar array deployed by Shuttle's remote manipulator. Design studies for a space-storable 25-kilowatt power system for the Shuttle and attached platforms were also completed. Studies were initiated to define the nature, utility, and cost benefits of a number of automated space facilities that promise to lower the cost of space applications and expand the user base. The science and applications platform and materials experiment carrier studies will define space platform concepts and materials processing in space payloads to take advantage of the 25-kilowatt power system. Geostationary platform and geosynchronous mission studies were continued. Proposals were received for the definition of the solar electric propulsion system planned to be used for high-energy planetary and cometary missions in the mid to late 1980s. Orbital transfer vehicle concepts for missions beyond the capability of planned STS upper stages continued with the selection of two vehicle contractors and three engine contractors. The orbital transfer vehicle would be a reusable vehicle to transport Shuttle pay-

loads to Earth orbit, lunar orbit, and planetary missions.

Innovative equipment and tools to further the utility, effectiveness, and flexibility of the Shuttle, as well as reducing the cost of operations, are being developed. Their functions include placement, retrieval, and in-orbit maintenance and repair of satellites and retrieval of unstable satellites and space debris. EVA tools and support equipment studies are under way. The preliminary design was completed for the open-cab "cherry picker."

A large-structures space experiments and demonstration plan was generated, involving such "end-items" as a large deployable antenna and various beams and structures. All of these aspects of large structures will be needed for future space applications and science activities.

Expendable Launch Vehicles

NASA conducted 8 launches during 1979 with its Expendable Launch Vehicles consisting of the all-solid-motor Scout, the Atlas-Centaur, and the Delta. Of the 8 launches, 3 were for NASA scientific and application purposes and 5 were for a variety of other United States government and reimbursing customers.

Scout. This vehicle was used to launch a NASA Stratospheric Aerosol and Gas Experiment (SAGE), a NASA magnetic satellite (Magsat), and a reimbursable United Kingdom scientific satellite (Ariel 6).

Atlas-Centaur. This vehicle was used to launch 2 satellites during 1979; 1 was a DoD communication satellite and the second was a NASA scientific satellite (HEAO 3).

Delta. Three launches were conducted using this vehicle—one domestic communications satellite for Western Union, another for RCA, and an experimental satellite, called Scatha, for DoD.

Atlas F. A weather satellite was launched on an Atlas F by the Air Force for NASA and the National Oceanic and Atmospheric Administration. All launches attempted were successful, another 100-percent year.

Space Research and Technology

The ability to explore and beneficially use the space environment is critically dependent on the state of technology. The purpose of the space technology program is to advance the frontiers of capability in space by providing a sound technological basis for future missions. In so doing, this program also stimulates the generation of advanced concepts.

The program is organized into two areas, the first dealing with advances in the fundamental space disciplines and the second with the systems technology necessary to demonstrate the readiness for flight of new capabilities generated in the fundamental area.

Fundamental Technology

As the practical applications of space grow, the need for high density, onboard information storage capabilities becomes more pressing. During 1979 a novel concept called a "multi-layer magnetic lattice file" was successfully demonstrated. This concept builds on magnetic bubble memory technology, which has now evolved to a stage of commercialization and provides increased data storage capability with minimum photolithographic dimensions. Future space recorders will have storage capacities up to fifty times greater than those currently available for the same size, weight, and power.

In thermal protection, during 1979 two new insulation materials were developed which will be used on selected portions of future Shuttle orbiters. The advanced flexible reusable surface insulation is a silica, quilted-felt material that will be used on the upper areas of the orbiter which experience moderate reentry heating replacing the current material at substantial cost savings. The fiber reinforced composite insulation is a silica reinforced insulation with 20 percent aluminum silicate fiber. This material is twice as strong and has higher temperature capability than the current reusable surface insulation.

During the past year, the feasibility of mass-producing very thin silicon solar cells and incorporating them into lightweight, high-performance solar arrays has been demonstrated. Since 1978, 5000 of these cells have been manufactured, with half of them having energy-conversion efficiencies of about 12 percent, a number approaching that of the best individually made silicon cells.

Space radiation damages solar cells and seriously degrades their power output. Thermal annealing (heating) of solar cells in space is one way to alleviate this problem and increase the lifetime of a satellite. Annealing mechanisms for silicon and gallium arsenide solar cells are being studied. It has been found that annealing for one hour at 400–450°C is sufficient to restore 90 percent of the power lost by silicon solar cells that have received radiation equivalent to 10 years in geosynchronous orbit. Gallium arsenide cells also exhibit attractive annealing behavior, with nearly complete restoration possible at temperatures of only 250°C.

One factor limiting the life of batteries in both space and terrestrial applications has been the dur-

ability of the separators used to prevent contact between active materials. Separator material under investigation by NASA for a number of years has been improved in the past year so that the useful life of batteries using nickel, silver, and zinc as active materials can be tripled, and separators can be made using more environmentally acceptable materials. This promises to extend the life of satellites and spacecraft, and could contribute to practical electric automobiles.

In the launch vehicle propulsion area, 1979 saw the successful initial testing of high-pressure primary combustors and turbine-drive gas generators burning liquid oxygen and high-density fuels. Regenerative cooling, with liquid oxygen in an operating engine, was also demonstrated, thus confirming earlier heat transfer analyses and laboratory scale tests that predicted superior cooling capabilities of liquid oxygen, compared to fuels of typical density, such as RP-1.

Finally, the technology verification of ion propulsion neared completion. This entirely new form of propulsion capability will permit the consideration of missions to comets and other difficult interplanetary destinations heretofore considered impractical. This work is expected to provide the basis for future development of a solar electric propulsion rocket stage.

Systems Research and Technology

In systems research and technology, emerging fundamental technologies are structured into interdisciplinary programs leading to demonstration of technology readiness for advanced space systems. Such activities are organized into three main categories—information systems, spacecraft systems, and transportation systems.

Information systems. Information system technologies lead to advanced sensor and instrumentation systems to facilitate acquisition of data and to processing and transmission systems to convert that data for effective and timely user information exchange.

Current NASA photographic imaging systems rely on silicon, charge-coupled device (CCD) technology to provide sensing capability in the visible and the near-infrared portion of the electromagnetic spectrum. During this past year, NASA developed and tested technology for a new imaging system involving a 1 x 9 array of mercury-cadmium-telluride CCDs capable of extending this capability into the thermal, far-infrared portion of the spectrum. Future plans involve expanding the array size to 1 x 1000 elements for use in a solid-state, multi-spectral system for imaging the Earth and its resources.

Continuing emphasis has been placed on the NASA end-to-end data systems (NEEDS) program to define system configurations and develop enabling techniques and technology for NASA-wide information systems of the 1980s. During the past year an optical data storage system successfully demonstrated the use of a laser to record and read data on film at a density of over 7 million bits per square centimeter. With this performance, one optical storage unit can replace up to 100 high-density magnetic-tape storage devices. Also during 1979, a significant step toward very high-speed processing was taken with the completion of the design of a "massively parallel processor," a 128 x 128 array of discrete processing units. This device can perform image processing computations at speeds of over 6 billion arithmetical operations per second, thereby enabling the classification of an entire Landsat image in six milliseconds.

NASA has been continuing communications technology development to enable future spacecraft to operate efficiently with the new Tracking and Data Relay Satellite System (TDRSS). During FY 1979, test demonstrations were completed on two different antenna configurations; the S/Ku-band planar array and the electronically switched spherical array. The S/Ku-band antenna was designed to handle high data rates in the megabit-to-1.8-gigabit-per-second range. Both antennas were designed to point electronically to TDRSS.

Spacecraft Systems. Spacecraft systems technology contains the elements to provide future advances in spacecraft structures and their associated subsystem, including power generating systems, control systems, onboard propulsion, and utility distribution systems.

NASA has continued the large space systems technology (LSST) program to develop the technology for future spacecraft that may be assembled in space through some combination of deployable and erectable space assembly methods. This program provides technology for two principal types of large space systems: support structures such as platforms, trusses, and beams; and shaped structures such as antennas. Initial efforts have focused on developing fundamental understanding of the characteristics of such structures in space through ground simulation. As a result of truss assembly experiments in the neutral buoyancy tank at Marshall Space Flight Center, the time and capability limitations of man-assisted assembly methods were revealed; this caused NASA to increase program emphasis on technology for assembly aids, deployment, and automated assembly techniques. As one example, several new concepts for structural joints were developed to respond to high-speed, automated assembly procedures. Additionally, a deployable

truss constructed from very thin-wall aluminum tubing and very compact in packaging, was developed and tested. In the laboratory, this scale model performed well in tests for extension and lock-up performance. Future free-fall tests in a large vacuum chamber will evaluate the adequacy of the deployment scheme.

A 12-kilowatt deployable solar array is being readied for test demonstration on an early Shuttle flight. This array design is intended for use by NASA in possible Shuttle power augmentation systems and the solar electric propulsion stage (SEPS). During 1979, this 32-by-4-meter lightweight wing was successfully subjected to simulated acoustic and thermal vacuum tests. Along with previous simulated zero-g testing aboard a KC-135 aircraft, the tests provide confidence for the planned Shuttle flights.

Transportation Systems. Transportation system technologies provide data needed for both the development of future aerospace vehicle design concepts and the improvement of the current Space Shuttle design.

Continuing last year's dynamics test program in a number of NASA wind tunnel facilities, models of the mated Shuttle orbiter, external tank, and solid rocket boosters were subjected to flutter and buffet loads. Ground-wind-load tests were conducted, simulating conditions for the ascent trajectory. In all cases, the design characteristics of the Shuttle were validated and there were no indications of aerodynamics instabilities or other problems.

NASA's composites for advanced transportation systems (CASTS) program fabricated and tested a wide variety of large graphite-polyimide structural panels. Included among these pieces of test structure was an element of the Shuttle orbiter aft body flap. As an example of the potential payoff of this lightweight structures technology for future space transportation systems, this body flap, if fully developed, could save future orbiter vehicles 160 kilograms in structure weight. More than 75 percent of this weight reduction derives from capability of composite materials to function at higher temperatures than aluminum, thereby eliminating the need for thermal protection.

NASA plans to exploit the unique opportunity to extend entry research and improve its ability to employ ground test facilities by conducting full-scale testing on orbiter flights. Early orbiter flights will be instrumented in the "Orbiter Experiments" program (OEX) to provide lifting-entry experimental data. OEX instrument packages have been designed, and during 1979 the following progress occurred: the Shuttle infrared leeside temperature sensing experiment, to measure upper surface temperatures on the Shuttle, was subjected to a critical design review

preparatory to release for fabrication; hardware for the tile gap heating experiment approached completion and is currently being readied for the second Shuttle mission; the Shuttle entry air data system, to measure aerodynamic pressure, completed preliminary design; and hardware was completed for the aerodynamic coefficient identification package, which is being integrated into the orbiter for the first Shuttle launch.

NASA Energy Programs

NASA seeks to ensure the effective use of its experience and technology in support of national energy needs. Most of NASA activity in energy is reimbursable support for the programs of the Department of Energy (DOE).

Phosphoric Acid Fuel Cell Systems. NASA fuel cell expertise and capabilities developed in space applications have, for the past three years, been applied to terrestrial fuel cell technology in support of the national energy goals.

In support of DOE, NASA has completed technology verification tests of an advanced cell stack concept. This stack promises, through the reduction in electrolyte losses, a five-fold increase from 8000 hours to 40,000 hours of operational life. This longer life should allow for amortization of the capital investment in a fuel cell system. In addition, the new stack can be fabricated at a lower cost.

Automotive Research and Development. In 1972, NASA started providing technical consultation to the Environmental Protection Agency's automotive gas turbine program. With the growth and subsequent transfer of the program to DOE, NASA's role has continued to grow. Currently, under the programmatic direction of DOE, NASA is providing technical management of the turbine development project and the parallel Stirling engine project.

The automotive gas turbine program saw the completion of a development which improved the fuel efficiency of a Chrysler engine by 10 percent and identified directions for further improvements. In another automotive gas turbine development, a number of ceramic turbine parts have been successfully tested at a temperature of 1040°C. Two industry teams, General Motors Corp. and AiResearch/Ford, were awarded 5-year contracts to develop an advanced automotive gas turbine engine. The new engine should be available for road tests in mid-1983.

In the development of automotive Stirling engines, 1979 saw the initiation of engine component development, and the successful integration of a Stirling research engine into an American Motors stock car to gain understanding of installation problems associated with this new type of engine.

At the request of DOE (then ERDA) in 1976, NASA assumed technical management for research and technology elements of the electric and hybrid vehicle program. In 1979, NASA took delivery of the first electric car designed, using best available components, for the evaluation of electric vehicle systems technology. In preliminary tests the GE/Chrysler-built car achieved a range of 145 kilometers at a cruising speed of 70 kilometers per hour, a 50 percent improvement over electric vehicles previously tested.

Industrial Gas Turbine Technology. Since FY 1977, NASA's expertise and capabilities in aerospace power and propulsion systems have been applied to the development of technology for large gas turbine engines in direct support of DOE's stationary power generation programs.

NASA's Lewis Research Center working with industry has initiated two efforts in turbine technology to enable gas turbines to use coal-derived liquid fuels when they become available. The materials effort for turbine hot-section components is focused on the development of long-life ceramic coatings capable of surviving the hostile environment created by combustion of coal-derived liquid fuels. The combustor work is directed toward the efficient burning of synthetic fuels while also satisfying federal emissions standards. Verification is to be done with modified gas turbine engines.

Photovoltaic Conversion (Solar Cells). Although NASA developed solar cells to power satellites over 20 years ago, the first government program to apply them to terrestrial use was begun jointly by the National Science Foundation (NSF) and NASA in 1975. Management of this key element of the energy program was subsequently transferred to the DOE.

During 1979, NASA's Jet Propulsion Laboratory (JPL) was designated the lead center for photovoltaic technology development and applications by DOE. JPL will develop plans, establish budgets, and provide overall program management of the national photovoltaic program.

Two NASA-directed applications of photovoltaic power are now operational. At the Schuchuli Indian reservation in Arizona, solar cells are generating 3500 watts of electric power and the second demonstration, supported by the Agency for International Development, is in Upper Volta at the village of Tangaye where solar cells generate 1800 watts of electric power.

Wind Energy. NASA has been assigned responsibility for the technical management of large wind turbine development and demonstration efforts since 1973. The first large machine, capable of developing 100,000 watts of electric power, was completed in 1975. Two similar wind turbines, generating

twice that power, became operational in 1977 and 1978.

On June 15, 1979, a third 200,000-watt wind turbine having a 38-meter-long blade was dedicated at Block Island, Rhode Island, and on July 11, 1979, the largest wind turbine ever constructed was dedicated at Boone, North Carolina. Its 60-meter-diameter rotor can generate two million watts of power, enough for 500 homes. An even larger turbine, using new technology to reduce cost, will be operational in 1980.

In addition to managing these wind energy efforts for the Department of Energy, NASA is now working with the Department of the Interior's Water and Power Resources Service to supervise construction of a large wind turbine and to train operating personnel. This machine, to be operational at Medicine Bow, Wyoming, in 1981, may lead to construction of a "Wind Energy Farm" at that site.

Space Data Services

NASA tracks, receives telemetry from, and sends commands to all NASA spacecraft by means of two worldwide tracking networks, one for deep space missions and one for Earth orbital missions. Supporting these networks are a cluster of mission control centers and a large data processing complex, with the complete system tied together by a global communications system. This system also provides real-time data processing for mission control and orbit and trajectory determination, as well as routine processing of engineering and scientific telemetry from the spacecraft.

Operations

The tracking system provided continuing support to about 30 NASA Earth-orbital missions in 1979, including the newly launched HEAO 3 and Magsat satellites, and the Stratospheric Aerosol and Gas Experiment. The system also provided launch support for several satellites launched by other government agencies, commercial firms, and by foreign governments, and provided backup capability for a few spacecraft controlled by other government agencies. This was an extremely busy year for the Deep Space Network, which supported 17 interplanetary spacecraft. Some of their missions required significant advancement in the capability of the network, such as the Voyager 1 and 2 encounters of Jupiter and the Pioneer 11 encounter of Saturn.

Network Improvements

More sophisticated space missions, always pressing the boundaries of technology, continued to re-

quire extension of the capability of the network. In the Deep Space Network the conversion of the 26-meter S-band antenna to 34-meter S- and X-band units continued, allowing higher rates of data transfer from deep space. Another innovation to provide the capability required by the ever-increasing distances and improve the return data rates of planetary spacecraft was a technique called "arraying." This consists of using two separate antennas to collect data from the spacecraft and then electronically adding the signals together, producing the effect of a single antenna of larger diameter. This technique was experimentally used during the Voyager encounter with Jupiter and during the Pioneer 11 encounter with Saturn. The experiments were successful and improved signal reception.

In addition to the difficulties in data reception and spacecraft command resulting from the great distances of planetary spacecraft, these distances placed great demands on our navigation capability. This is particularly important when the missions require a close flyby of a planet to get an assist from that planet's gravity to alter trajectory and reduce travel time. We have used a navigation technique called "differential very long baseline interferometry," wherein two geographically distant antennas collect data from a known radio source, such as a quasar, as well as the spacecraft. Integration of this information provides precise positioning and reduces navigational uncertainties.

The Earth-orbital tracking system was also being improved to meet demands that are increasing in difficulty. The Shuttle flights will require voice communications; the required modifications were essentially completed. Preparations were begun for the very high data rates that will be experienced in Spacelab support.

Tracking and Data Relay Satellite System (TDRSS)

The TDRSS is a system of four data-relay satellites that will ultimately replace the ground tracking stations for support of low Earth-orbital missions. NASA has contracted with Western Union for the lease of services from the system for ten years. TRW is acting as the major subcontractor to Western Union in the spacecraft development portion of this system and that development is now moving along satisfactorily with the major subsystem having been delivered for integration and test. The ground station at White Sands that will receive TDRSS data is nearing completion as is the network control center at Goddard Space Flight Center, Greenbelt, Maryland.

General World Administrative Radio Conference (GWARC)

Every 20 years the GWARC convenes to revise the international regulations and frequency allocations that govern the use of the radio spectrum. With the tremendous increase in demand for these frequencies that has resulted from the advances in communications technology, this subject is of great interest to the United States and to NASA. The GWARC convened on September 27, 1979, with NASA supplying 4 of the 84 United States delegates. One hundred and forty-eight nations were represented by approximately 1700 delegates. NASA presented position papers on space research, land-mobile satellites, a solar power satellite, and remote sensing. Almost all space communication requirements were successfully negotiated during the conference.

Aeronautical Research and Technology

NASA's aeronautical research seeks improvements in the performance, efficiency, and safety of current aircraft and a base of high technology that designers can use to improve aircraft of the next generation. These objectives focus research onto:

- establishing and maintaining a strong technological base
- reducing energy consumption and undesirable effects of aircraft
- improving terminal area operations
- advancing long-haul and short-haul aircraft
- providing technical support for the military.

Maintaining a Strong Technology Base

The fundamental aeronautics research and technology program includes activities in all disciplines and provides for the continued advancement of technology and the establishment of a strong aeronautics technology base. Significant accomplishments in 1979 include the development of new airframe and engine component materials, improved computational techniques, advances in flutter prediction and control, and improved human-aircraft interface and air-system management.

The airframe materials research during 1979 continued to focus on composite structures. New, tougher graphite/epoxy composite materials were identified. These composite laminates, based on four new epoxy formulations, have survived laboratory impact tests at a strain almost twice that of presently used composite materials. Present composites permit a 25-percent weight reduction over aluminium structures; doubling the maximum allowable design strain

for composite structures will significantly increase the potential weight savings.

Materials research for propulsion systems has continued to provide materials with the strength and oxidation/corrosion resistance required for higher engine operating temperatures. A ceramic material, zirconium oxide, has been used in an abradable turbine engine shroud seal. The shroud used a compliant layer between the ceramic surface and the metallic backing to relieve thermally induced strains that might delaminate or crack the ceramic. The seal has successfully completed 1000 thermal cycles at 1300° without failure. Replacement of conventional seals with ceramic seals can lead to a 10-fold reduction in the wear of turbine blade tips, with a resulting reduction in specific fuel consumption by about 2 percent.

For the first time, an analytical computer code successfully described the flow characteristics through both stationary and rotating propulsion system components. The internal flow was modeled by using a three-dimensional viscous analytical technique having high computation speed, and a large enough number of mesh points to analyze the complex flow, including secondary cross flows and vorticity. This model has been verified by experimental measurements in actual turbofan mixers. Knowledge of the dynamics of the mixing of the flow in the engine will contribute to future improvements in engine performance and jet noise reduction.

During 1979, significant advances were made in computational aerodynamics research. For the first time, a computational solution was obtained which predicts and explains the details of the unsteady behavior of flow over wings and other lifting surfaces at transonic speeds. When compared with data obtained on a fighter aircraft, the solutions showed that both the onset and magnitude of buffet effects were as predicted.

The trend toward lighter, more flexible structures for aircraft requires new methods of predicting and avoiding flutter instability. During FY 1979, an active control concept, based upon a computer-implemented feedback control system, was successfully tested in the wind tunnel. Twelve transducers on the airfoil surface sensed the onset of flutter and transmitted this to the computer; the computer activated existing flaperons to produce aerodynamic forces that oppose flutter. The model airfoil with the active controls was able to attain a velocity 50 percent greater than the flutter onset without the controls. The technique is being tested currently in flight tests with a radio-controlled drone.

In the joint NASA-FAA cockpit display of traffic information (CDTI) and heads-up display (HUD) programs, results from laboratory studies using static

symbology indicated that HUD-experienced pilots are able to simultaneously perceive both symbolic (HUD) and real-world information. A simulator study using dynamic HUD symbology is presently under way to quantify pilot responses. A generic display concept was developed and experiments conducted to provide a data base on crew perception of lateral separation, using CDTI.

Reducing Energy Consumption and Undesirable Effects

NASA made progress in 1979 toward its goals of developing technology that would reduce fuel consumption in derivative and future commercial subsonic transport aircraft by as much as 50 percent.

Engine Systems. Looking toward near-term fuel savings in current production and derivative JT8D, JT9D, and CF6 turbofan engines, NASA selected 16 engine components for advanced technology improvements. Work has been completed on 7 of these and the demonstrated fuel savings have been very close to predictions. Four are already in production by the aircraft engine industry: an improved fan, a new short-core nozzle, a more rigid front engine mount for the CF6 engine, and an improved high-pressure-turbine active clearance control system for the JT9D engine. The new technology is particularly timely, since new derivative engines are under development.

The information generated by the NASA investigations to isolate and quantify the causes of performance deterioration in engines and their resultant loss in fuel efficiency has been adopted by a number of airlines; results have been a one-percent improvement in cruise specific fuel consumption and a reduction in costly unscheduled engine removal rates of as much as 50 percent. If all the engine improvements and diagnostic techniques are adopted by the industry, a cumulative fuel savings of 33 billion liters could be realized over the next 25 years that these engines are produced and in service.

Looking further into the future, NASA is developing technology for a new generation of turbofan engines that will be extremely fuel-efficient, resistant to performance deterioration, and economical to operate and maintain. Engine system designs were completed in 1979, and the major hardware phase of the program was initiated. Overall estimates of engine system performance indicate that these new energy-efficient engines could reduce fuel consumption by 14 to 22 percent depending on the flight mission, reduce direct operating cost by 5 to 10 percent, reduce performance deterioration by 50 percent, and decrease noise and emission levels below those of the most advanced engines in service today.

High-speed propeller technology is being developed for application to commercial transports and short-haul commuter aircraft. Subscale model tests have validated the design tools for modern, advanced-technology propeller configurations that could reduce fuel consumption by 15 to 20 percent over turbofan engines of the same technology level. The design was completed on the latest in a series of propeller models: a ten-bladed configuration with low blade tip speeds to reduce propeller noise. This configuration is estimated to be about 20 decibels quieter and one percent more efficient than any models previously tested.

Aerodynamic Systems. Aerodynamics research for reducing energy use in transport aircraft continued to make good progress in 1979.

In mid-1979, a KC-135 tanker aircraft, modified to incorporate winglets, completed its first flight under a joint NASA-USAF research program. To be completed in 1980, the flight program is expected to demonstrate a 6-8-percent reduction in cruise drag compared to the unmodified KC-135.

Wind tunnel investigations of advanced high-lift systems for transport aircraft wings have led to new flap configurations that are significantly better than current devices, demonstrating 30-percent higher maximum lift. Including this capability in advanced wing design would provide improved operating efficiency in the takeoff, climb, and descent phases of flight.

Removal of the turbulent (high drag) air layer that flows close to the wing surfaces could improve the energy efficiency of transport aircraft by 20 to 40 percent depending on the extent of application and on aircraft range. In 1979, wing surface panels incorporating the necessary slots and porous surfaces to restore laminar flow were built and tested under simulated flight environments in preparation for actual flight test of these state-of-the-art concepts on a wing leading edge next year. The design of an optimum airfoil, tailored to the specific requirements for active removal of the turbulent boundary layer, has been completed, and testing will take place in the near future.

Structural Systems. A major effort is being expended to accelerate the acceptance of fiber-reinforced composite structures for transport aircraft. The potential benefit from this technology is structural weight savings up to 25 percent for fuel savings of 10-15 percent. The current program consists of developing the technology for secondary structures and medium primary structures.

In the secondary-structures program during 1979, the DC-10 rudder program was essentially completed, with FAA certification and planned airline service. Five shipsets of B-727 elevators have been

manufactured, all ground and flight testing completed, FAA certification obtained, and airline service begun. The design phase of the L-1011 aileron was also completed and the first full-scale part fabricated.

The design phase for the medium-sized primary-structure components has been completed. The principal B-737 stabilizer subcomponents (stub box) have successfully completed static, fatigue, and fail-safe testing and the first full-scale B-737 stabilizer was fabricated. Skins and spars for a full-scale L-1011 vertical fin have been fabricated, and DC-10 vertical-stabilizer fabrication has begun.

Fuels. Aviation jet fuels research and technology are directed at investigating variations in the properties of future jet fuels derived from petroleum and non-petroleum sources, and studying the potential effects of these varying properties on performance of engines and fuel systems. Results to date indicate that a major problem is the increasing amount of aromatic hydrocarbon compounds; these generally burn with a smokey, luminous flame, because excessive soot forms in the combustion process. The likely variations in the properties of future jet fuels have now been established and activities are under way to develop the combustor and fuel-system technologies needed so that these fuels can be used with acceptable levels of emissions and durability.

Noise and Emission Reduction. An extensive systematic study on effects of inlet geometry and flow on the noise radiated from aircraft inlets has been conducted. Test results from an advanced "scooped-inlet" concept show that the ground-measured noise level could be reduced as much as 10 decibels, compared to that from a conventional symmetrical inlet.

Experimental engine testing of an advanced combustor applicable to small engines was conducted during 1979, and reductions in carbon monoxide emissions of 50 percent and unburned hydrocarbon emissions of 80 percent were demonstrated. Preliminary design of several lean prevaporized/premixed combustor concepts were analytically evaluated and two of these concepts were selected for experimental evaluation. If successfully developed, these would provide extremely low emission levels in both the airport environment during taxi, landing, and takeoff, as well as in the upper atmosphere during high-altitude cruise.

Improving Terminal Area Operations and Safety

Research on terminal area operations and safety is being pursued vigorously by NASA.

Terminal Area Operations. In 1979, the NASA-FAA program to develop technology for advanced airborne systems and for flight procedures for more efficient operations in the terminal area demon-

strated advanced airborne guidance, control, and display systems which aided flight crews operating the NASA Terminal-Configured Vehicle (TCV) B-737 at Denver and an L-1011 at Dallas. These tests were conducted under actual Air Traffic Control (ATC) conditions to fly minimum-fuel descents to fixed approach entry points within a few seconds of assigned arrival times, as compared to two-minute variations using conventional systems, and were conducted with the air traffic controller acting only in a monitoring capacity. The results have provided support to airlines and the aircraft industry for the incorporation of such concepts in the development of new aircraft; benefits include improved safety, fuel efficiency, and system productivity.

Safety. NASA's safety research included studies of new elastomeric material blends for tires meeting demands of high-performance aircraft. Flight tests of tires based upon a NASA-developed formulation showed improved wear, but exhibited chevron-cut growth. In an effort to avoid these undesirable tendencies, tires are now being processed using advanced blending and curing techniques and will be tested in the NASA Landing Loads Track at the Langley Research Center.

The Aviation Safety Reporting System continues to be important to NASA's aircraft safety program by providing a flow of confidential safety information from the users of the National Aviation System. Approximately 100 voluntary reports are received by NASA each week, and are used as a basis for issuing alert bulletins and conducting special studies to analyze trends and recurring problems. One of the special studies in 1979 involved the analysis of cockpit distractions that led to hazards identified in reports. It was concluded that 33 percent of the distractions were non-operational in nature, such as requests over the company radio, the public address system, and interruptions by flight attendants. The remainder were distractions from operational activities, such as checklists, minor malfunctions, and watching traffic. The detailed analyses of the types and causes of distractions provided an important input to the air carriers to improve their crew training and operational procedures.

Advancing Long-Haul and Short-Haul Aircraft

Efforts continued to develop and prove the technology for long-range supersonic aircraft, very quiet short-haul aircraft that operate at very low approach speeds, and rotorcraft and general aviation aircraft, which are becoming increasingly important elements of short haul transportation.

Supersonic Research. Research continued on propulsion, aerodynamics, and structures technologies that would enable design of supersonic aircraft that

could be economically attractive and environmentally acceptable. Two variable-cycle engine-component test rigs reached the stage of all-up testing in FY 1979. One concept, the double-bypass engine, successfully demonstrated noise reductions of 6–8 decibels, confirming small-scale model tests of the co-annular noise principle. The other concept, a variable stream control engine, demonstrated very high duct burner efficiency, with low levels of exhaust emissions. High-lift devices have been tested which improved the low-speed efficiency of highly swept arrow wings by 12 percent over the best achieved two years ago. Titanium design and manufacturing process studies continued; with the Air Force, NASA began the design and one-step fabrication of a complete super-plastic-formed, diffusion-bonded, titanium horizontal tail for a small supersonic airplane. NASA's AD-1 oblique-wing research aircraft made its first flight on December 21 from Dryden Flight Research Center. Though the wing was in the usual position perpendicular to the fuselage for this flight, it can be pivoted as much as 60° for investigation of handling characteristics.

Quiet Short-Haul Aircraft. NASA activity in propulsive-lift short-takeoff and landing (STOL) aircraft research has increasingly been concentrated in flight testing. In 1979, research with the C-8 jet augmentor wing and Twin Otter propeller STOL research aircraft was essentially completed in such areas as control compensation following engine failure in the landing approach, examination of the influence of night visual cues on pilot landing performance, and automatic STOL landings using the microwave landing system.

Following completion early in 1979 of proof-of-concept flights on NASA's quiet short-haul research aircraft (QSRA), flight-envelope documentation flights began. Takeoff ground rolls of less than 203 meters, landing ground rolls less than 168 meters, and low turn (to 183-meter radius) capability have been demonstrated. Analysis of the latest test data indicates that the QSRA is performing very close to preflight predictions from wind-tunnel data and, in particular, has demonstrated the capability of obtaining the very low noise characteristics necessary for STOL operations.

Rotorcraft. In 1979, wind-tunnel tests determined means to improve airflow in rotor hub and pylon areas with marked reduction in drag. Other wind-tunnel tests were started on a newly acquired full-scale research rotor that incorporated some of the desirable features determined from scale-model testing and analysis.

Full-scale tunnel tests also demonstrated a unique advanced rotor system known as the X-wing; it operates as a rotor in helicopter flight and as a

fixed wing in an X-configuration in high-speed forward flight.

Flight data were gathered on the use of airborne radar as a navigation aid in landing approaches to oil rigs in the Gulf Coast. This will assist the FAA in establishing criteria for terminal-area instrument procedures.

A major effort completed in 1979 was the formulation by a NASA task force of an advanced rotorcraft technology program. NASA also conducted a highly successful rotorcraft modeling workshop with wide participation by the helicopter community.

General Aviation. NASA made gains in 1979 in its research in general aviation to improve energy efficiency, environmental impact, safety, and utility.

In 1979, NASA conducted full-scale cooling drag tests in the Ames Research Center's 40 x 80-foot wind tunnel using a semi-span model of a general aviation wing and nacelle combination. The tests demonstrated that exhausting the cooling air through exits in the nacelle's side rather than via standard cowl flaps can provide better cooling and significantly reduce drag from cooling.

The quiet, clean, general aviation turbofan (QCGAT) engine program was successfully completed, and the primary program goals were met. In pollutant emissions, there was a 54-percent reduction in carbon monoxide, 76-percent reduction in unburned hydrocarbons, and significant reductions in nitrous oxides. The QCGAT engine noise was 10 to 14 decibels lower than the most quiet of current business jet engines.

The most severe test in the joint NASA-FAA general aviation crash dynamics program was performed at the Langley Research Center's Impact Dynamics Research Facility. A twin-engine aircraft was crash-tested at a 30-degree nose-down attitude using small rockets to increase impact velocity to 145 kilometers per hour. Two NASA-designed energy-absorbing passenger seats were tested in the controlled crash. One was a rocker motion seat designed to rotate the passenger into a more acceptable position at impact. The other was a ceiling-suspended seat that uses the wire bending principle to dissipate energy. Both restraint systems attached to the seat instead of to the fuselage as in conven-

tional design. The test results indicate that the seats reduce occupant load up to 50 percent, thereby providing a better chance to avoid serious injury in the event of a crash.

Technical Support for the Military

Since most of NASA's aeronautical program addresses broad-based fundamental problems, considerable potential military benefit accrues from much of the NASA program.

Highly Maneuverable Aircraft Technology (HiMAT). A major joint program involving the USAF and NASA that deals with the technology of high-performance aircraft is the HiMAT program. The HiMAT remotely piloted research vehicle, a 44-percent scale model of a potential future concept, made its first flight on July 27, 1979, from Dryden Flight Research Center. This was not only the first step in validating the very advanced technologies used in the vehicle design, it also demonstrated a new flight-test technique (i.e., sub-scale, remotely piloted research vehicles) that offer significant cost reductions for future flight research.

Tilt Rotor Research Aircraft. The NASA-Army tilt rotor research aircraft has been successfully flown over a speed range from 0 to 382 kilometers per hour. After completing hovering flight and documenting the aircraft's flight characteristics at various combinations of forward speed and rotor tilt angle, the aircraft was flown with the rotors tilted forward in the airplane mode for the first time. The Navy has now joined with NASA and the Army in this program to obtain data on the tilt rotor concept applicable to future V/STOL aircraft options that meet Navy requirements.

Rotor Systems Research Aircraft. The rotor systems research aircraft program, another NASA-Army program, reached a major milestone with the delivery of both research aircraft to the Ames Research Center. The two vehicles, one in the helicopter configuration and the other in the compound configuration (wing and auxiliary thrust engines added), are now being flown in familiarization and instrumentation systems checkout in preparation for starting research flights.



Introduction

Space and aeronautics are areas of major interest to the Department of Defense because they are fundamental to the national security. DoD therefore operates a strong program with a wide scope of activities in space and aeronautics. These activities range from research and development that maintains the flow of fresh technology to the phasing in of new concepts and systems for more efficient fulfillment of requirements in such areas as communications, command and control, navigation, environmental forecasting, surveillance, and experimentation. While the purpose of these activities is military in nature, DoD maintains close cooperation with other agencies of the government through which benefits from the DoD program reach the civilian sector. In 1979 there was notable progress in a broad range of space activities, including the start of construction of a Space Shuttle launch facility on the west coast and the bringing to full operational strength of the space segment of a global DoD communications network. Aeronautics progressed with flight-test programs of several advanced concepts and promising new electronic systems.

Space Activities

Military Satellite Communications

Satellite communications systems are being employed to meet priority communications needs that are unique to worldwide DoD communications requirements. These systems are also used to establish high-priority alternate routing for certain terrestrial systems to improve survivability, and to reduce dependence on third nations to approve communications access to other countries. The flexibility offered by this medium to rapidly reconfigure existing communications networks to meet crisis management requirements and provide direct communications to task force commanders is important as a force multiplier.

Defense requirements for satellite communications call for three categories of capability: (1)

high-capacity, high-data-rate, long-haul, point-to-point communications for fixed users; (2) moderate-capacity, low-data-rate communications for mobile users; and (3) command and control of strategic nuclear forces. Military satellite communications systems for these mission must be hardened against nuclear effects and have jamming protection to maintain communications and command/control continuity in a hostile or crisis environment. Currently these three categories of capability are satisfied by (1) the Defense Satellite Communications System Phase II (DSCS II); (2) Fleet Satellite Communications System (FLTSATCOM), plus leased services on the Marisat satellite system (Gap-filler); and (3) the Air Force Satellite Communications System (AFSATCOM), consisting of communications packages on the Satellite Data System (SDS), and FLTSATCOM. During the coming decade, these existing systems will be replaced and augmented in an evolutionary manner by (1) DSCS III, (2) Leased Satellite (LEASAT) System, and (3) Strategic Satellite System (SSS).

Defense Satellite Communications System (DSCS). The mission of the DSCS is to provide secure voice and high-data-rate transmissions in support of unique and vital requirements for worldwide military command and control and crisis management, intelligence data relay, early warning detection, monitoring and surveillance, and diplomatic traffic. The DSCS supports critical, global communication requirements of the National Command Authorities, the Worldwide Military Command and Control System (WWMCCS), the Ground Mobile Forces, the Defense Communications System, the Diplomatic Telecommunications Service, the White House Communications Agency, and selected allies. Now fully operational, the space portion of DSCS consists of four active satellites and two on-orbit spares and provides global (less polar) coverage with near 100 percent availability through the 1980s. To ensure continuity of essential communications and survivability during crises situations and a potential hostile communications environment, evolving DSCS satellites will include an improved

anti-jam capability in addition to nuclear-effects hardening.

The initial research and development phase of the Defense Communications Satellite Program provided a limited operational system from 1966 through 1974. For most of 1979, the space subsystem consisted of four operational spacecraft and one on-orbit spare: one DSCS II satellite (number 4) launched in December 1973, two DSCS II satellites (numbers 7 and 8) launched in May 1977, and two DSCS II satellites (numbers 11 and 12) launched in December 1978. The successful December 1978 launch of satellites 11 and 12 permitted the return to NATO of the NATO IIIB satellite which was on loan for temporary use because DSCS II satellites 9 and 10 failed to achieve orbit in March 1978. DSCS II satellites 13 and 14 were successfully launched in November 1979, achieving the desired six-satellite configuration for the first time. DSCS II satellites 15 and 16 will become available as replacements in 1980.

The next generation of DSCS satellites will be DSCS III models, with improved performance and survivability. During 1979, development of a qualification-model satellite, two R&D flight satellites, and ground command and control equipment continued. The first R&D satellite (DFS 1) is planned for a dual launch with DSCS II number 15 and will undergo about six months of R&D test and evaluation; it will then be turned over for operational use. The second R&D satellite (DFS 2) is planned for a dual launch with DSCS II number 16 and will undergo a comparable test period before being placed into operational use.

The DSCS III satellite will have multiple, independent transponders for efficient handling of both small and large terminals. It will provide a three-fold increase in channel flexibility, will have improved anti-jam protection through multiple-beam antennas capable of nulling or minimizing uplink jamming signals, and will provide responsive adaptability in reallocating power and bandwidth assets. In addition to the normal S-band tracking, telemetry, and command functions operated by the Air Force Satellite Control Facility (SCF), the DSCS III satellite will have a super-high-frequency command capability, controlled operationally by the Defense Communications Agency. This capability will improve response time for reconfiguration of antenna systems. The satellite will conform to nuclear survivability guidelines and is being designed for an on-orbit life of ten years. Since the Space Shuttle will become operational during the life of the DSCS III program, the new satellite is being designed to be Shuttle-compatible.

Fleet Satellite Communications System (FLTSATCOM). Moderate capacity, mobile-user service will

be provided by the FLTSATCOM. Its objective is to develop, procure, and implement a satellite communications system to satisfy the most urgent, worldwide, tactical peacetime and crisis management communications requirements of the Navy and strategic communications requirements of the Air Force. Production contracts for five FLTSATCOM spacecraft have been awarded and the first two spacecraft were launched in February 1978 and May 1979, respectively. The third spacecraft was scheduled for launch in January 1980. Installation of fleet broadcast receivers is virtually complete, with systems installed in approximately 420 ships and 109 submarines. Additionally, over 236 ships are now equipped for reliable long-range secure voice operation. Shipboard terminal equipment is now operating through both the MARISAT and FLTSATCOM systems.

Beginning in 1982 this class of service will be provided through the lease of UHF satellite service (LEASAT) from the commercial sector. This LEASAT system will initially supplement and eventually replace FLTSATCOM satellites as they approach the end of their service life.

Air Force Satellite Communications. The Air Force Satellite Communications (AFSATCOM) System provides communications for command and control of strategic and other selected nuclear-capable forces. The initial operating capability of the system was achieved in May 1979. The space segment includes UHF transponders on FLTSATCOM and the Satellite Data System (SDS). Upgraded transponders with increased jam-resistance are being integrated into the first DSCS III satellites as a secondary payload, with first launch planned for the early 1980s. AFSATCOM terminals are being installed in ground command posts, airborne command posts, and the strategic bomber force. Additional terminals are being procured for ICBM launch control centers.

Satellite Data System (SDS). The Satellite Data System provides critical two-way, transpolar command and control for nuclear-capable forces as well as supporting the data communications network for the Satellite Test Center and the remote tracking stations.

Strategic Satellite System. Evolutionary improvements to the AFSATCOM system are planned. These improvements to the space segment include development of additional jam-resistant transponders for the Satellite Data System and the NAVSTAR Global Positioning System and possibly a new satellite specifically conceived to provide highly survivable communications into the 1990s. These space segment improvements and the terminal upgrades will become available in gradual steps and

are collectively referred to as the Strategic Satellite System.

Satellite Communications Ground Support. The Army Satellite Communications Agency is responsible for the development and acquisition of strategic and tactical satellite communications ground terminals for use by all services. Two major projects in this program element are the DSCS and the Ground Mobile Forces Tactical Satellite Communications Programs. A third and smaller project in this program is devoted to the exploratory development required to support the two major projects.

During 1979, there was significant activity related to the ground terminals supporting the DSCS II system. All 18 of the new AN/FSC-78 heavy terminals were operational the entire year, meeting critical user requirements. The second-year buy of AN/GSC-39 medium terminals took place in 1979, bringing the total on contract to 12. A third-year buy for an additional 9 terminals will be funded in 1980. Procurement of 10 more medium terminals to replace the aging and obsolete AN/TSC-54 and AN/MS-46 terminals is planned for 1982. Also, the first of the new AN/TSC-86 transportable JCS contingency satellite terminals were deployed in late 1979. Continued success was experienced in the contract for the new anti-jam multiple access equipments (AN/USC-28), with the first of these units scheduled for delivery in September 1980. All large, fixed military satellite terminals employed in support will be equipped with these new anti-jam modems.

Tactical Satellite Communications. Delivery of the initial buy of 31 multichannel SHF tactical terminals (AN/TSC-85, AN/TSC-93) was completed in 1979, and 12 of these terminals will be deployed to the U.S. Army in Europe for use with the DSCS II space segment. In September 1979, a production contract for 225 additional terminals was awarded, with first deliveries in 1981. When fully deployed, these SHF terminals will provide mobile, multichannel communications for the ground mobile forces transmitting from the field through the DSCS satellites. Production was begun of 210 UHF vehicular terminals (AN/MS-64) to be used with the FLTSATCOM satellites beginning in 1981. Testing was completed on the UHF manpack terminal (AN/PSC-1), and a multi-year contract award for a total of 174 terminals for special Army users is expected in 1980.

Navigation Satellite Activity

The NAVSTAR Global Positioning System (GPS). NAVSTAR GPS is a joint-service program to provide a capability for three-dimensional, high accuracy, continuous, worldwide navigation. The

operational NAVSTAR GPS will consist of constellations of satellites in three orbital planes at 20,400 kilometers, a ground segment for calibration and control of the satellites, and numerous user equipments of various classes. The GPS will provide all-weather coverage on a common grid, enabling users passively to determine position to within 10 meters and velocity to within .03 meter per second. The system will also provide precise worldwide time transfer.

Developmental models of all classes of user equipments, including high accuracy, low-cost, and manpack models, have been and continue to be field tested with the four GPS satellites launched in 1978. The desired prototype user-equipment accuracies were achieved, completing the concept-validation phase in June 1979. Full-scale engineering development was initiated in August 1979, with initial operating capability expected in the mid-to-late 1980s. Launch of the fifth GPS satellite is planned for February 1980.

Meteorological Activities

Defense Meteorological Satellite Program (DMSP). During 1979, the Air Force-managed DMSP satellite system continued to support DoD strategic and tactical needs for weather information with three Block 5D satellites in orbit. The Navy continued to expand its use of DMSP's high-resolution imagery and sounder data both ashore and afloat. The global, stored satellite data are now routinely transmitted to the Fleet Numerical Oceanography Center, ingested into the numerical air-ocean model's global data base, and the imagery is retransmitted by computer to the other major naval oceanographic prediction centers. The Air Force Global Weather Central (AFGWC) continues to routinely process data into its real-time global data base for worldwide strategic applications, and is installing a satellite data handling system which will permit real-time interaction of the meteorologist with the computer data base. The imagery is transmitted from the satellite in real time to transportable read-out stations at key locations worldwide to support Army, Navy, and Air Force tactical operations. In 1979, the Navy continued to improve its tactical read-out program by the addition of the fifth direct read-out unit to the Fleet. The fourth Block 5D satellite was launched and became operational in July 1979 and is providing excellent meteorological information. In addition to cloud imagery, this satellite provides vertical temperature profile information from a new microwave sensor system and ionospheric data from several other special sensors. AFGWC is now using the plasma probe information for real-time analysis and fore-

casting of ionospheric electron content. This represents the first use of real, in-situ measurements of space environmental data. Also in 1979, the joint Air Force-Navy DMSP instrument development procurement program produced final design and contract award for a passive microwave imager that will provide quantitative values of precipitation, cloud and liquid water content of the atmosphere, ocean surface wind speed, and sea ice distribution. This new family of DMSP instruments will be flown in 1981-1984.

Surveillance Activities

Early Warning Satellites. Early warning capabilities reside in an integrated system of ground-based radars and a constellation of three geostationary satellites for earliest indication of a hostile ballistic missile launch against the United States. During 1979, a successful launch replaced one of the older satellites that was failing. Development continued on modifications to ensure compatibility of early warning satellite payloads with the Titan 34D and Shuttle Inertial Upper Stage (IUS) as well as improvements in the survivability of the satellite and ground systems.

Space Surveillance. The current capability for locating, tracking, and identifying objects in space is provided by a network consisting primarily of ground-based radar sensors deployed for purposes other than space surveillance—for example, missile warning. This sensor network has a limited capability to detect objects above 5500 kilometers altitude and has gaps in the coverage below this altitude. DoD is procuring a Ground-Based Electro-Optical Deep Space Surveillance system for comprehensive detection and tracking of satellites at high altitudes.

A viable approach, in the long-term, for responsive surveillance up to geosynchronous altitudes appears to lie in spaceborne sensors. Several R&D activities to develop this technology are continuing. For example, the Air Force has developed detector modules for a mosaic staring sensor which is expected to provide improved survivability.

The Defense Advanced Research Projects Agency (DARPA) continued in 1979 development of advanced concepts and technology for strategic and tactical surveillance from space. Radiation source monitoring from space is being demonstrated with the DARPA 301 gamma ray spectrometer, placed in orbit by the USAF Space Test Program in early 1979; the experiment is operating successfully, including demonstration of the long-life cryogenic refrigerators developed for this flight. The experiment has achieved the highest gamma-ray spectral

resolution measured in space. Development of infrared surveillance technology for mosaic detector arrays, signal processing, cryogenic refrigerators, and large optics and structures continued, with successful laboratory testing of a new generation of infrared detector array and large, actively controlled mirror elements. The Teal Ruby space experiment to demonstrate detection of aircraft will use first-generation infrared mosaic detector arrays and is entering the qualification testing phase, with launch expected aboard the Shuttle in late 1982. DARPA has initiated the advanced sensor demonstration program to demonstrate advanced surveillance missions and the technology base developed to support them; an advanced space system is in the design phase, with launch planned in FY 1987. Technology development was initiated for key components of space-based radar concepts with emphasis on broad mission applications for the technology base, a philosophy that was successful in the definition of the infrared technology needs. In 1979, DARPA continued conceptual designs for the Talon Gold experiment, which will develop space technologies for support of precision acquisition, tracking, and pointing at long range.

Space Shuttle Activities

Inertial Upper Stage (IUS). The IUS is under development by the Air Force to deliver DoD spacecraft to higher orbital altitudes and inclinations than the Shuttle alone provides and will also be used by NASA for their synchronous-orbit payloads and planetary missions. DoD will also use the IUS on the Titan III to improve mission success during the early transition period to Shuttle. During 1979, full-scale development continued, having started in April 1978; other procurement involved IUS ground support equipment, logistics support, and necessary modifications to the Solid Motor Assembly Building at Kennedy Space Center.

Controlled Mode at Johnson Space Center (JSC). Shuttle launches will use NASA's JSC for simulation, training, and flight control for DoD Shuttle missions. In 1978, a special ad hoc Shuttle security group of the Aeronautics and Astronautics Coordinating Board (AACB) completed validation of the controlled mode concept to provide the capability to conduct classified DoD Shuttle missions out of JSC with minimum impact to concurrent civil space operations. The AACB approved the recommendation of this ad hoc group, and both DoD and NASA initiated implementation of the controlled mode. In 1979, efforts were concentrated on detailed system design, software validation and verification, and determination of facility modifications. A preliminary

design review was held in early October. Initial operating capability for the controlled mode is expected in early 1982 to support the initial classified DoD payloads on Shuttle. The investment in controlled mode is being held to a minimum consistent with essential security needs and projected DoD workload on Shuttle through the mid-1980s.

Vandenberg Air Force Base (VAFB) Shuttle Launch Site. Efforts continued during 1979 to acquire Shuttle launch and landing capabilities at Vandenberg Air Force Base (VAFB), California. Vandenberg facilities are required by both civil and DoD users for polar launches, complementing Kennedy Space Center (KSC) which will launch to low-inclination orbits, such as geosynchronous equatorial deployments. Commonality of equipment and procedures between KSC and VAFB is being maximized to minimize acquisition costs and operations complexity.

The requirements definition contract for VAFB was completed in mid-1978. The follow-on effort, to design unique support equipment, develop and acquire the launch processing and computer applications software, and prepare installation designs is nearing completion. Facility construction began in January 1979.

Space Boosters

The DoD family of space boosters is comprised of the Atlas and Titan III standard launch vehicles as well as surplus Thor (LV-2D, LV-2F, SLV-2A) and Atlas E/F ICBM vehicles. Nine DoD space missions were successfully launched in 1979: 5 on Titan IIIs, 1 on LV-2F Thor, 1 on Atlas-F, and 2 which were launched by NASA (1 on Delta and 1 on Atlas-Centaur). In addition, DoD launched 1 NASA-NOAA mission on an Atlas-F. Integration of the Inertial Upper Stage (IUS) with the Titan III launch vehicle family, begun in June 1977, continued through 1979. As DoD transitions its payloads to Shuttle, the expendable launch vehicles will be phased out at a rate dependent on progress with major development and orbiter delivery milestones of the NASA Space Transportation System.

Space Test Program

The Space Test Program provides space-flights for test and evaluation of DoD R&D experiments and certain operational spacecraft not authorized their own means for space flight. Three payloads were successfully flown in 1979.

Spacecraft Mission P78-1, known by its primary payload the gamma ray spectrometer, was launched on February 24 from Vandenberg AFB on an At-

las-F. It carried seven payloads. Spacecraft Mission P78-2, also referred to as the spacecraft charging at high altitudes (SCATHA) mission, was launched on January 30 from Cape Canaveral Air Force Station on a NASA Delta launch vehicle. The twelve experiments comprising the SCATHA payload, three of which are NASA's, were to provide the data to determine methods for protecting spacecraft systems in geosynchronous orbit from transient outages and electronic malfunctions caused by spacecraft charging. Finally, Spacecraft Mission S78-1, also referred to as the Navigational Package (NAVPAC) mission, was flown on a host vehicle and tested a geodetic package.

The program will now serve as the pathfinder for DoD to exploit ways to use the manned Shuttle as a laboratory in space. This exploitation approach will expedite infusion of new technology into space systems through the use of simpler, incrementally designed, man-aided systems. New hardware will be developed and procured to enable this exploitation. A contract award is expected in 1980.

Space Research and Technology

Space-related research and technology by the Department of Defense includes efforts defining the space environment and assessing its effect on the performance of DoD systems operating within it.

Solar Radiation Monitoring Program. The Navy solar monitoring program in 1979 consisted primarily of developing additional applications for operational predictions of propagation phenomena affecting HF and VLF radio systems. Solrad Hi and Goes satellite data provided significant real-time solar measurements for the research and development of a prediction system under evaluation at the Naval Communication Station, Stockton, California. The Naval Research Laboratory continues to explore basic research studies in solar physics, solar-terrestrial relationships, and plasma process to determine these solar effects on Navy systems and operations.

As part of the continuing Air Force technology program in prediction of propagation environment, solar processes are being investigated and solar emissions are measured. The programs in solar emissions include the theoretical study of the processes leading to solar flares, in which the Air Force Geophysics Laboratory works closely with the National Science Foundation's Sacramento Peak Observatory. Techniques to forecast the time history of high-energy solar particles that may impact the Earth following a major solar flare are still in the development stage. The Air Force is installing a worldwide radio-solar-telescope network for

use with the Solar Optical Observing Network. In 1979, the radio solar telescope in Australia became operational.

Air Force scientists are also participating in rocket and satellite observations of solar ultraviolet (UV) emissions. Working closely with NASA scientists, Air Force personnel are studying the variations in solar UV observed by spectrophotometers on Atmosphere Explorer C, D, and E satellites. Rocket flights designed to measure solar UV flares between 230 and 3500 Angstroms continue to be flown and, in conjunction with satellite measurements, used to develop models of the solar UV emission spectrum.

Environmental Remote Sensing. The Air Force Geophysics Laboratory has a continuing program to monitor space environment-induced effects as observed at the surface of the Earth. Scientists are measuring ionospheric scintillation and signal delay at a number of ground stations around the globe, using transmissions from beacons on both orbiting and geostationary satellites. These measurements indicate signal statistics for satellite communication systems and Air Force surveillance radars.

Spacecraft Charging Technology. The Air Force Geophysics Laboratory (AFGL) is actively involved in the joint USAF/NASA spacecraft charging technology program. In addition to developing theoretical and empirical models of the natural environment leading to spacecraft electrical charging at synchronous altitude, AFGL continued preparation of a handbook that will document the full range of variability of charged particles and fields that can be expected at this altitude. Data from the Air Force Scatha satellite, launched in January 1979, are being used to update the models and the handbook. Scatha satellite instrumentation, supplied by the Air Force, includes electrostatic analyzers, charged particle flux spectrometers, and electron and ion beam systems to assess the feasibility of actively controlling satellite charging and discharging. Close coordination between the interdependent activities of the Air Force and NASA continues through the joint USAF/NASA spacecraft charging technology program. Models of the energetic electron flux at satellite altitudes will be implemented to measure energetic electrons in the 110-megavolt range, showing the dosage rates received by satellite microcomponents.

Advanced Space Communications. The advanced space communications program develops and demonstrates advanced spacecraft and airborne/ground terminal technologies to meet future DoD needs for military satellite communications systems. In 1979, new space components were developed for operation in the higher EHF frequency bands. These

higher frequency bands are being investigated as a means of relief from frequency spectrum congestion being experienced in the lower frequency bands and as a means of enhancing protection against jamming. Efforts are also under way in laser communication technology to provide significant improvements in jamming protection as well as very-high-data-rate transmissions. The Air Force Space Division has completed a developmental model ground test phase at a White Sands, New Mexico, test range. A follow-on phase, currently in progress, will integrate a laser communications terminal into an EC-135 aircraft for air-to-ground tests in FY 1980. An orbital laser communications package is also under development for launch on the Teal Ruby spacecraft in late 1982 aboard Shuttle.

Other Technological Activities. Under the space vehicle subsystem technology program, spacecraft subsystem improvements are in progress that will be important to the survivability, autonomy, performance, power, and weight of DoD satellites in the 1980s. An improved magnetic bearing momentum wheel, for better satellite stability, will complete environmental testing of a new wheel material in early 1980. The space sextant, which will be important to future autonomous satellite operation and improved survivability, entered the flight-unit fabrication and qualification test phase. Development of the fault tolerant spaceborne computer, which will enhance survivability by minimizing satellite dependence on ground stations, has been accelerated toward a demonstration flight in 1984. Also major advances were made in the magnetic bubble memory technology for a solid state spaceborne memory that will provide a hardened, non-volatile data storage capability. In satellite space power systems, efforts continued on the a 50-amp-hour nickel-hydrogen battery intended to replace nickel-cadmium units, as well as on a high-efficiency solar panel employing gallium-arsenide and silicon solar cells.

Space Ground Support

DoD space activities were principally supported in 1979 by the Air Force's Eastern and Western Space and Missile Centers, Satellite Control Facility, and Arnold Engineering Development Center; and the Army's White Sands Missile Range. These facilities, available for use by Federal agencies, industry, and other nations, support a wide variety of test and evaluation activities. In October 1979, Air Force Systems Command (AFSC) realigned its space and missile development and acquisition elements. Space Division (SD), which reports directly to Hq AFSC, has assumed the space-related activ-

ities previously the responsibility of the Space and Missile Systems Organization (SAMSO), which was deactivated. The Eastern Test Range at Patrick AFB, Florida, has become the Eastern Space and Missile Center, while the Western Test Range at Vandenberg AFB, California, has become the Western Space and Missile Center.

Eastern Space and Missile Center (ESMC). ESMC has the responsibility to support a variety of DoD space and ballistic missile operations, NASA space programs, and commercial or international satellite launches under the sponsorship of NASA. Current improvement emphasizes the enhancement of telemetry, radar tracking, and range safety. During 1979, ESMC provided support to Navy testing of Poseidon and Trident fleet ballistic missiles. Launch and data-acquisition support was provided to NASA's programs, satellites for commercial organizations, and operational space payloads for the Air Force. ESMC was also actively engaged in conducting planning and analyses in support of the Space Shuttle, which will be launched for orbital test flights from the Kennedy Space Center.

Western Space and Missile Center (WSMC). WSMC provides range tracking, data acquisition, and flight safety support for all ballistic missile and space launches, as well as aeronautical tests at Vandenberg AFB. Approximately 50 ballistic missile, space launches, and aeronautical flights were conducted in 1979. The major aeronautical program was the cruise missile. WSMC is actively engaged in planning for the Space Shuttle launches from Vandenberg AFB, which involves extensive construction of launch, logistic, and maintenance facilities. Launch pad construction for Shuttle was begun in January 1979.

Satellite Control Facility (SCF). During 1979, the SCF supported 17 launches, including 9 DoD missions, 1 NASA mission, and 7 ballistic flights. Requirements for network support continued to grow, with 86,900 contacts totaling 68,400 hours of support. With the addition of a second antenna at Thule, Greenland, and the British Telemetry and Commanding Station at Oakhanger, United Kingdom, the SCF now has 12 tracking stations at seven sites worldwide. Significant maintenance efforts included the replacement of the antenna azimuth bearing at the New Hampshire station and replacement of the radome over the 18-meter antenna in Hawaii. Also, modifications were completed for SCF participation in the orbital flight test of the Shuttle. A major data system modernization effort was started, which will replace aging computers at the remote sites and consolidate telemetry, tracking, and commanding functions into a centralized system at the Satellite Test Center. When operational

in 1983–1984, this system will enlarge capacity and reduce operating expense.

White Sands Missile Range (WSMR). The Army's WSMR continued to provide support to DoD and NASA aeronautics and space programs. A full spectrum of launch, flight, and recovery services was provided, including ground and flight safety, surveillance, command and control, data acquisition, and analyses. NASA program support included the Space Shuttle, the calibration rocket program, upper atmospheric sounding with rockets and balloons, and variety of astronomical test programs. Specific Space Shuttle activities included qualification tests on the orbital maneuvering system and on forward and aft reaction control systems, evaluation of Shuttle spacecraft materials, training of astronauts to land the Shuttle, and a satellite system to track and relay Shuttle position data back to earth.

Arnold Engineering Development Center (AEDC). AEDC provides essential aerodynamic, space environment, and propulsion tests to accelerate development of aeronautical and space systems. Its crucial value can be measured by the fact it has supported virtually every major U.S. aerospace program. Its 40 test units provided approximately 50,000 test hours in 1979 to support missile projects, the Space Shuttle, and space launch rocket motor tests. An Aeropropulsion Systems Test Facility will be ready in 1983 to test large, high-performance turbojet and turbofan engines in a more realistic environment than can be attained today. Another test unit in planning is the Turbine Engine Load Simulator (TELS). TELS will be a centrifuge that will stress engines to simulate an inflight environment and at the same time x-ray the engine to determine abnormalities caused by "g" forces. TELS will contribute greatly to reductions in development and maintenance costs.

Aeronautical Activities

Aircraft and Airborne Systems

F-16 Multimission Fighter. The first production F-16 aircraft were received by the United States and Belgium in January 1979 while the Netherlands received their first production aircraft in June 1979. The remaining European partners, Denmark and Norway, will begin receiving production aircraft in 1980. The multinational operational test and evaluation (MOTE) was initiated in January 1979 at Hill AFB, Utah. These tests are providing information on the capability and suitability of the F-16 to perform its operational missions. In addition, development testing is continuing to resolve deficien-

cies that have been previously identified in aircraft systems.

B-52 Squadrons Development Projects. The development projects under the B-52 squadrons address a variety of avionics programs all essential to the effectiveness and survivability of the B-52 force. One critical effort is the continuation of the program for the offensive avionics system (OAS)—phase one. This project develops for B-52G/H modification an update to the bombing navigation system incorporating nuclear hardened, digital subsystems in place of the 1950 vacuum tube technology. Additionally the OAS also integrates the air launched cruise missile (ALCM) on the B-52G. Because of the critical schedule requirements to deploy the ALCM and update the avionics, development and procurement are being considered concurrently. Initial options for the modification contract were negotiated between January and July 1979, and the contract was issued in August 1979. The first of the modified aircraft will be available in 1981. A second critical item to the bomber mission is surviving the effects of nuclear explosions. New programs will have hardness included, but aircraft systems not scheduled for replacement will require, as a minimum, protection against electromagnetic pulse (EMP). Analyses and studies began in 1976, but in 1979 the program received new emphasis, with the B-52 being exposed to the electromagnetic pulse at two facilities during the year. Joint DoD, Air Force, and contractor teams are currently reviewing the EMP programs in view of the test results and will make recommendations to increase the probability of aircraft surviving the EMP threat. Because this threat could affect all airborne and ground digital systems, progress on B-52s will be closely monitored for potential use in other programs.

A-10 Close-Air-Support Aircraft. The Air Force plans to procure 733 A-10s to provide a specialized close-air-support aircraft. Research and development is complete, except for integration of new systems being added to improve effectiveness. Of the 627 aircraft approved for production, approximately 300 have been delivered to tactical forces in the United States and Europe. The Air Force activated its first wing and two Air National Guard squadrons in the United States as well as an initial wing of four squadrons, with later growth to six wings, in the United Kingdom. The aircraft in the United Kingdom will also operate from four forward locations in Germany. Favorable reliability and maintainability factors have been demonstrated, so the anticipated low operating costs should be realized.

F-15 Air Superiority Fighter. Limited development efforts are continuing on the F-15 to complete electronic countermeasure updates and to provide other component improvements. These efforts include development of a programmable signal processor; this expansion of the capability of the radar system will permit future improvements through software changes rather than more expensive hardware modifications.

Delivery of production F-15 aircraft is continuing. By the end of FY 1979, a total of over 430 of the 729 total planned F-15s had been received by the Air Force. Delivery of F-15C and D model aircraft began in June 1979. This improved version features a 1000-kilogram increase in fuel capacity, provisions for low-drag conformal fuel tanks, and increased maximum takeoff weight of 30,900 kilograms. The remainder of the F-15 programmed procurement will be C and D model aircraft.

F/A-18 Carrier-Based Strike Fighter. The Navy's F/A-18 aircraft is the replacement for the remaining Navy and Marine F-4 Phantom fighters as they reach the end of their service life. It will also replace the aging A-7 light attack aircraft in the mid-1980s. Introduction of this aircraft into the fleet will provide the tactical commander at sea with a high-performance, agile strike fighter, capable of surviving in hostile territory. The Secretary of Defense has approved full-scale development of this aircraft. The first flight was in November 1978, and a total of eleven full-scale development aircraft are scheduled for delivery.

EF-111A. The EF-111A is designed to provide defense suppression radar jamming in support of United States and Allied air operations. The peacetime mission will be to provide training for operations in an electronic countermeasures environment for our own air defense and tactical forces. The EF-111A is in limited production, which includes a test effort to evaluate the correction of deficiencies identified during earlier tests. Flight-test data to date indicate the EF-111A is surpassing all reliability performance requirements.

Advanced Attack Helicopter (AAH). The advanced attack helicopter continued in full-scale engineering development during 1979. The initial prototype target acquisition designation systems (TADS) and pilot night vision systems (PNVS) were delivered by both competing contractors, for use in system integration and checkout. The two Phase I flight prototype helicopters were returned to flight status after completing modifications which converted them to the Phase II configuration.

The first airborne firing of a Hellfire ballistic missile from the AAH took place on March 3, 1979. The firing was successful, with no detrimental ef-

fects on the aircraft. This and other successful ballistic launches led to the first guided Hellfire launch from the AAH on September 18, 1979. The first autonomously designated launch of a Hellfire from an AAH (fired from the AAH as designated by the target acquisition designation system on the same aircraft) was successfully completed on October 20, 1979.

CH-47 Modernization. The CH-47 modernization program is designed to ensure that the Army will have a medium-lift helicopter capability beyond the year 2000. An engineering development effort which began in June 1976 has produced three prototype CH-47D models which incorporate seven modernized systems: rotor, drive, hydraulic, electrical, advanced flight control, cargo handling, and auxiliary power unit. These changes are to improve the reliability, availability, maintainability, productivity, safety, and survivability, and produce one standard CH-47 configuration to facilitate logistical support and maintenance. All three prototypes have begun contractor flight testing and will be tested by U.S. Army personnel in the field beginning in January 1980. Once the test results have been analyzed, a decision on full-scale production of the completely modernized CH-47 will be made. The Army plans to have an entire unit of 24 CH-47Ds in the field by mid-1983.

E-3A Airborne Warning and Control System (AWACS). The E-3A Wing at Tinker AFB, Oklahoma, reached operational status in April 1978. By the end of 1979, 19 E-3A aircraft were delivered to the Tactical Air Command providing an all-altitude, airborne radar surveillance and command and control system with good survivability. The total United States E-3A force is programmed for 34 aircraft. The NATO defense ministers approved a NATO airborne early warning and control (AEW&C) program which includes the procurement of 18 E-3A aircraft, the upgrading of ground communication links, and the preparation of support bases and facilities. NATO is also funding development of an improved E-3A computer to increase the system's tracking capacity. This program is the largest acquisition ever undertaken by NATO. United States developments are focused on further improvements in capability.

Development continued on incorporating into the E-3A the joint tactical information distribution system (JTIDS) to provide jam-resistant, secure communications between the E-3A aircraft and other users. Flight testing of the JTIDS terminal in the E-3A aircraft was completed with successful demonstration of the pertinent performance requirements, and plans are to initiate full-scale development of a fighter aircraft terminal in 1980.

Tomahawk Cruise Missile. Tomahawk is a high-subsonic-speed, turbo-fan-powered, long-range cruise missile sized to be fired from a submarine torpedo tube, but also capable of being launched from surface ships, aircraft, and mobile ground platforms. This missile is being developed in two forms, a conventionally armed anti-ship version and a nuclear-armed land attack version.

The anti-ship Tomahawk will provide an important complement to carrier-based aircraft in extending the Navy's anti-ship capability over a broad ocean area. The stand-off capability afforded by Tomahawk will pose a credible threat to enemy surface forces at minimum risk to our launch platforms.

The nuclear land-attack Tomahawk could provide a flexible nuclear force for theater or strategic roles. Its ability to penetrate with its single warhead and high accuracy and its survivability make it particularly suitable for use in limited nuclear attacks.

Tomahawk is planned for installation on nuclear attack submarines and cruisers. A ground-launched version of Tomahawk is being developed for the Air Force.

Air-Launched Cruise Missile (ALCM). A competitive "flyoff" between the AGM-86B and the AGM-109 air-launched cruise missiles (ALCM) was conducted during 1979 and early 1980 with ten launches each. Flight-test results are being evaluated along with contractor cost and technical proposals. Source selection and a production decision are to be made in March 1980.

Current plans are for a maximum ALCM production rate of 40 per month. This is consistent with the B-52G modification rate and supports the "shoot and penetrate" concept of initial B-52G/ALCM deployment. The first alert capability of the B-52G with externally loaded ALCM is scheduled for September 1981, and the initial operating capability of the first B-52G squadron is planned for December 1982.

Ground-Launched Cruise Missile (GLCM). GLCM will be part of the modernization of the long range theater nuclear force to bolster deterrence, protection against failure of conventional forces, and theater nuclear firepower. The Air Force plans to procure 560 missiles for deployment to Europe. The GLCM system will integrate the Tomahawk cruise missile into an air-transportable, ground-mobile system which consists of a transporter-erector-launcher and a launch control center. The system is now in full-scale engineering development with initial operating capability planned for December 1983.

Advanced Strategic Air-Launched Missile (ASALM). ASALM is being developed to enhance the

strategic bomber force, which includes the B-52, FB-111, and future strategic carriers. ASALM is a long-range supersonic missile capable of neutralizing the Soviet air-defense interceptors and warning aircraft, as well as suppressing defenses and striking primary targets. A propulsion technology validation program was established to demonstrate the ASALM integral rocket ramjet propulsion system. This flight-test program consists of seven flights between October 1979 and April 1980. Initial test results appear very favorable. The next phase will be a subsystem demonstration validation which will emphasize air-to-air guidance development, and will begin in early 1980.

Pave Low III. Operational evaluation of the Aerospace Rescue and Recovery Service's Pave Low III combat rescue system has been completed at Military Airlift Command's Kirtland AFB, New Mexico, and the first production unit was completed in 1979. Pave Low III, when integrated into an H-53 helicopter, provides the Air Force with a highly sophisticated, advanced system that will permit low-level penetration and recovery of downed airmen in hostile territory in darkness and adverse weather. Necessitated by an increasingly lethal enemy threat that will outdate current rescue tactics, the system employs forward-looking infrared devices, terrain avoidance/following radar, and inertial/doppler navigation in its rescue/penetration operations.

Aeronautical Research And Development

Advanced Technology Concepts. The DoD research, development, test and evaluation (RDT&E) program continued to sponsor a myriad of activities for the national defense. Its DoD science and technology program sponsors activities in research, exploratory development, and advanced technology demonstrations. Technological areas extend from propulsion for aircraft, missiles, and space systems; to guidance and control, communications, and electronics; through materials, structures, and information processing; and through environmental sciences to the vital areas of safety and life sciences. Technological applications in aeronautics and space are developed to meet more sophisticated requirements of current and projected programs. During 1979, efforts in advanced electronics—electro-optics, microwave, and computers—continued to drive technological improvements for aeronautical and space systems.

Electro-optics technology is being incorporated in many devices, such as infrared and charge-coupled imagers, signal processors, ring laser gyros, fiber optics, and displays. These devices are finding their way into improved aeronautical systems such

as target designators, range finders and trackers, optical search and tracking devices, miniature solid-state TV cameras, and navigational systems.

Advances in microwave technology continue to provide improvements in microwave-power-generating efficiencies and in electronic package miniaturization through the use of recently developed solid-state components.

Emphasis continues on computer science technology as computer processing requirements become more integral with the total aeronautical system. Today's aircraft contain as many as a dozen minicomputers, handling functions such as navigation, altimetry, fire control, weapon delivery, search, and flight control. Recent developments in mass memory capabilities are allowing development of correlation by computer of stored mapping information with terrain features sensed by radar or passive radiometers, thus providing precise navigation over long distances.

A major new initiative was begun in 1979 on integrated circuits with the very high speed integrated circuits (VHSIC) program based on silicon technology. The objective of this six-year program is to accelerate the availability to DoD of high-speed integrated circuits featuring submicron sizes. These integrated circuits will provide new or significantly increased capabilities in satellites, avionics, cruise missiles, radar, and digital signal processing. It is expected that one VHSIC will replace 50 or more present integrated circuits—at least a ten-fold reduction in size, weight, power consumption, and failure rate with concomitant savings in both initial and life-cycle costs. The projected 200-fold increase in signal processing will increase by a factor of ten the accuracy in cruise missile targeting and synthetic-aperture-radar ground mapping during evasive maneuvering of attack aircraft, as well as a low probability of intercept by air surveillance radars.

Research in Aircraft Propulsion Systems. The advanced turbine engine gas generator (ATEGG) program is the main Air Force propulsion program assessing core engine components under realistic test conditions. Traditionally stressing durability and performance, the program has been increasing in scope to include life-cycle costing and structural testing earlier in the engine development cycle. Accomplishments in 1979 include initial tests of a new generation of gas generators, successful completion of the first dedicated structural/durability test and continued demonstration testing of variable-area, high-temperature turbines employing advanced materials. Future efforts will emphasize comprehensive durability assessment, including accelerated life testing of components.

The aircraft propulsion subsystems integration (APSI) program is a multi-faceted Air Force effort. The joint technology demonstrator engine (JTDE), a joint Air Force-Navy program, is a part of APSI. High-pressure turbine engine cores from ATEGG are integrated with new low-pressure components (fans, compressors, and fan turbines) to form a full-scale technology demonstrator engine (the JTDE). When combined with independent demonstration and assessment of inlets, exhaust nozzles, and afterburners the tests characterize advanced engine technologies as complete propulsion systems. Accomplishments in 1979 include initial demonstration testing of the JTDEs, initial application of life-cycle cost models, verification of structural life prediction/correlation models, and assessment of operational benefits for variable cycle engines. Follow-on JTDE testing will emphasize comprehensive mechanical integration/performance testing and durability/life characterization.

The Army is conducting a competitive demonstrator engine program in the 800-shaft-horsepower size. The overall objective of this project is to provide an advanced technology option for future Army aircraft and other defense needs. This program has as its goals a 50–60 percent improvement in specific power and 20–25 percent improvement in specific fuel consumption over present in-service engines. Initial test results have been promising.

Aircraft Structures and Materials Technology. Each of the services has R&D programs directed toward improved structures and materials for aeronautical and space applications.

The Air Force is determining the suitability of cast aluminum for primary aircraft structures, offering a minimum 38 percent cost saving with no weight penalty. A full-scale forward fuselage bulkhead from a cargo aircraft was redesigned from over 400 parts and 3000 fasteners to a one-piece cast aluminum structure with no fasteners. Testing to validate structural integrity is nearing completion. Primary adhesively bonded structure technology is also being developed by the Air Force. Through the use of adhesive bonding, fabrication of large cargo aircraft structures such as fuselages can be reduced from the labor-intensive assembly of thousands of parts to the assembly of a few large bonded modules. The Air Force has conducted an advanced technology demonstration program to design, fabricate, and test a full-scale, 13-meter-long fuselage section using adhesive bonding in place of conventional riveted fastening. The test structure has successfully completed four lifetimes (76,000 pressure cycles) of fatigue testing, some of which was performed with intentional damage in the form of saw cuts up to 20 centimeters long. A significant

reduction in the propagation of such damage in the adhesively bonded structure, as compared to conventional riveted structure, was observed. This structural safety improvement contributes an additional five percent to the originally projected structural weight savings of 15 percent using adhesive bonding. Cost savings of 30 percent were also demonstrated, principally from the elimination of over 80,000 fasteners.

In 1979, the Army initiated a two-phase program called advanced composite aircraft program (ACAP). Phase I, which is the preliminary design phase, will develop advanced composite design concepts for the primary structure of the next generation of U.S. Army helicopters. Phase II will flight-demonstrate two of the most promising concepts. Future benefits will include minimum weight and reduced manufacturing cost plus reduced radar cross-section and improved ballistic survivability.

Forward Swept Wing. Advanced composite materials with inherent characteristics that allow tailoring of the aircraft structural features has led to the development of the forward swept wing (FSW) concept. FSW offers the designer increased configurational flexibility that can translate into greater transonic maneuverability, lower transonic wave drag, and improved low-speed handling qualities. A DARPA program in 1979 validated the capability to design a divergence-free FSW through wind tunnel tests of large-scale semispan models. Investigations will be undertaken in 1980 toward the development of a flight demonstration vehicle.

Advanced Flight Control Concepts. In 1979, the Air Force completed flight tests of a YF-16 aircraft modified to provide independent six-degree-of-freedom control. The tests demonstrated the feasibility of providing independent control about all axes to improve accuracy of weapon delivery. The results of these tests are being incorporated into the Air Force fighter technology integration (AFTI) program, where the aircraft fire control system is integrated with an advanced flight control system to provide even greater accuracy improvement. AFTI is scheduled to begin flight tests in 1981.

Advanced Helicopter Rotor Systems. The Navy advanced helicopter rotor system program is directed toward demonstrating the flight feasibility of the circulation control rotor (CCR) concept. CCR is a non-articulated rotor in which aerodynamic angle of attack is achieved by boundary layer control. The first flight of a CCR mounted on a modified Navy/Kaman H-2 helicopter took place in September 1979, and the test program is expected to continue through 1981. The X-wing is a stopped rotor concept that incorporates CCR technology. Feasibility of the X-wing concept, which

is being jointly developed by DARPA and the Navy, was demonstrated through full-scale wind tunnel tests of a 7.6-meter-diameter rotor. Transition between rotary wing flight and fixed wing flight, and vice versa, was demonstrated in excess of 30 times during these tests. A small (1700-kilogram) demonstrator aircraft program will be initiated in 1980. Additionally, testing has been conducted on a high-speed, counter-rotating rotor called the advancing blade concept (ABC) as part of a joint Army-Navy-NASA program. Advantages of this concept include improved maneuverability, low noise, high hover efficiency, and the ability to perform high-speed flights at high altitudes. Testing to date has documented these advantages, and evaluations of this high-speed rotor will continue through FY 1981.

Synthetic Flight Training Systems (SFTS). Following Army testing, the flight simulator for the CH-47 helicopter became standard in June 1978. This simulator uses a closed-circuit television system in conjunction with a three-dimensional terrain model to provide a realistic visual display, the first Army flight simulator with such a capability. The first production article of the CH-47 simulator was placed on contract in early FY 1979. The prototype continues to be used in an aviator training program at Fort Rucker.

The AH-1 flight and weapons simulator (FWS) is the first to incorporate weapons engagement along with other flight maneuvers. The evolution will continue with the development of the UH-60 Black Hawk flight simulator which will use a camera model board for one cockpit and a computer-generated imagery visual system for the other cockpit. Testing in 1979 evaluated the training benefits of these two technologies. Concept formulation and development are underway for the AH-64 flight and weapons simulator which will have the capability to produce the sound and fury of the battlefield. Testing of the simulator is scheduled for 1982.

Remotely Piloted Vehicles (RPV). The Army remotely piloted vehicle (RPV) system performs target acquisition, designation, aerial reconnaissance, and artillery adjustment missions. A small unmanned air vehicle, including its mission payload, is controlled from a ground control station, with the plane's video imagery and target location information returned via an anti-jam data link. Between October 1, 1978, and September 30, 1979, administrative and contractual arrangements were made to conduct engineering development of a remotely piloted vehicle system. A contract was awarded on August 31, 1979, for the full-scale engineering development. Hardware deliveries will

consist of 22 air vehicles, 18 mission payload subsystems, four ground control stations, and three launcher and recovery subsystems. First flight of the system is scheduled for late 1981.

Relationships with NASA

Aeronautics and Astronautics Coordinating Board

The Aeronautics and Astronautics Coordinating Board (AACB) is the primary mechanism for addressing major policy issues of interest to DoD and NASA in space and aeronautics. In 1979, the Board was extensively involved in reviewing the NASA Space Shuttle development and orbiter production program, and the DoD program for Shuttle use. Both agencies made adjustments in their respective programs.

As Space Shuttle development has progressed, performance margins have changed because of design and equipment changes as well as weight growth. To allow for further improvement in the Shuttle's capability, NASA has considered a number of options for providing thrust augmentation, and presented to the AACB in early 1979 the decision that such a project, if undertaken in future years, would use two strap-on solid motors, one on each of the Shuttle's large solid rocket motors (SRMs). Correspondingly, the Air Force agreed to modify the VAFB Shuttle launch pad design to accommodate the thrust-augmented Shuttle configuration if needed. NASA has also baselined a second thrust-augmentation approach using liquid boost modules (LBM) that employ Titan technology. This LBM approach is also compatible with the revised VAFB launch pad design. Thus, either strap-on solid motors or LBM thrust-augmentation approaches can be accommodated.

Board members have extensively reviewed NASA's Shuttle developmental problems and recent schedule changes. The First Manned Orbital Flight (FMOF) on Shuttle is now scheduled for late 1980, while Kennedy Space Center (KSC) is now to begin launching operational flights in 1982. Orbiter 099 is scheduled to be delivered in 1982, Orbiter 103 in 1983, and Orbiter 104 in 1984. This revised schedule will support the DoD plan to begin the transition of operational spacecraft to launch on Shuttle in FY 1983 and to complete this transition by FY 1986.

NASA and the Air Force reached formal agreement in March 1977 on the cost of Space Shuttle flights for DoD missions. Entitled "NASA/DoD Memorandum of Agreement on Basic Principles for NASA/DoD Space Transportation System Launch Reimbursement," the agreement establishes the

DoD cost for the standard Space Shuttle delivery flight at \$12.2 million in FY 1975 dollars. Discussions are currently underway to expand this agreement to include optional services, such as the additional time on orbit that will be required for certain defense missions. Discussions are also under way on the basic principles which will guide sale, by the Air Force, of the Inertial Upper Stage (IUS) to NASA, other civil, and foreign customers.

National Aeronautic Facilities Program. In its final form as defined by DoD and NASA, the National Aeronautic Facilities Program contains three large facilities necessary to continue the efficient development of aeronautical technology and systems through the end of this century. The facilities contained in the program are:

- **AEROPROPULSION SYSTEMS TEST FACILITY (ASTF)**—sponsored by the Air Force to support the economical development of advanced engines for fighter, large strategic transport, and bomber aircraft.
- **NATIONAL TRANSONIC FACILITY (NTF)**—sponsored by NASA to permit research and development testing at high Reynolds number in the transonic mach-number range (combines the requirements of the earlier High Reynolds Number Tunnel, sponsored by the Air Force, and the Transonic Research Tunnel, sponsored by NASA).
- **40×80 FOOT SUBSONIC TUNNEL MODIFICATION**—sponsored by NASA to meet subsonic research needs for the study of rotor craft and large powered-lift vehicles.

Significant progress continued on all three facilities during 1979. Their completion and activation are scheduled for the early 1980s.

Cooperative Programs/Efforts

DoD continued to actively participate in joint activities with NASA and other agencies during 1979. Efforts already described are the solar radiation monitoring program, spacecraft charging technology, and activities associated with the Space Shuttle. Other areas of interest:

Space Launch. The major space launch vehicles used by NASA have characteristically been direct applications or derivatives of Air Force ballistic missile systems (Thor, Atlas, and Titan). The Air Force provided Atlas E/F launch to NASA for National Oceanic Atmospheric Administration (NOAA) satellites, and the Air Force 6595th Space Test Group manages the prelaunch checkout and launch of such systems. Air Force personnel at both the ESMC and WSMC launch sites provide support to NASA for range operations, range safety, tests, and procurement.

National Oceanic Satellite System (NOSS). A joint study by NASA, NOAA, and DoD has shown that NOSS, under joint agency management, could meet most operational oceanic measurement requirements of both the civil and military communities. NOSS is being initiated as a limited operational demonstration project intended to prove the utility of a routine, repetitive set of related and synoptic space measurements from which the required global ocean surface information (sea height, sea surface temperature, ice cover and age, sea currents, ocean wind field, and water color and turbidity) can be extracted. A new real-time ground processing and user data distribution system will be a key feature in proving NOSS's utility. NASA will have lead responsibility for developing the space segment with DoD sharing costs, while NOAA and DoD will share responsibility for ground segment development. Development and operation will be jointly managed by the three agencies with control shifting to NOAA and DoD in the later phases of the demonstration. Alternative concept studies for system configuration will commence in early 1980.

Helmet-Mounted Display Technology. The Air Force Aerospace Medical Research Laboratory (AFAMRL) has provided a helmet-mounted display/sight apparatus for testing at NASA's Johnson Space Center (JSC). This display will be installed in the Space Shuttle simulator to test its utility for providing critical information for final approach and landing of the Shuttle. Per a Memorandum of Agreement between AFAMRL and NASA, AFAMRL will provide NASA with the hardware of the visually coupled system, consult on the interface design, and be responsible for the installation of this equipment in the Space Shuttle simulator. JSC has provided funding in FY 1979 and FY 1980 to initiate the development of advanced helmet-mounted display electronics, and will make available all technical information from this effort.

Atmospheric Research. The joint effort between NOAA, NASA, and USAF which produced the U.S. Standard Atmosphere (1976) continues. That joint publication has disseminated the wealth of knowledge on the upper atmosphere obtained during the past solar cycle. Extensive rocket and satellite data acquired over more than one complete solar cycle are incorporated. This stratospheric measurement capability will provide important spin-off benefits to the National Plans for Stratospheric Research and Monitoring which are now being prepared at the Federal level as a result of the growing concern over ozone depletion and environmental deterioration.

During 1979, a large, coordinated program under

the auspices of DoD, NASA, and the National Research Council of Canada was conducted to measure the response of the middle atmosphere and lower ionosphere to the February 1979 solar eclipse. During the eclipse, DoD's Atmospheric Sciences Laboratory was mainly interested in the electron density in the lowest portion of the ionosphere, since DoD communications and radar signals are affected by the electrons and ions in this area. The rapid day-to-night-to-day transition afforded by the eclipse provided a rare opportunity to observe how the presence and absence of solar radiation affects the atmosphere. It is expected that the 1979 solar eclipse program will serve as a forerunner for the middle atmosphere program in 1980-1985.

KC-135 Winglets. The joint USAF/NASA KC-135 winglet demonstration program is an advanced development program with the objective of proving, through flight testing, that the total of aircraft drag reduction can be achieved with winglets. Winglets are small airfoils of optimum shape located at the wing tip in a near vertical position. Drag reduction translates into a fuel saving which is dependent on aircraft fleet utilization rates. Based on recent rates, an 8-percent drag reduction on the KC-135 tanker aircraft could save 164 million liters of fuel annually. Winglets also increase the tanker off-load capability because less fuel is used to transit to and from the refueling point.

The Air Force has completed the modification of a KC-135 aircraft, and flight testing to validate a predicted eight percent improvement in range began in June 1979. This development will have application to both commercial and military transports.

Rotor Systems Research Aircraft (RSRA). A joint Army-NASA contract has led to the completion and acceptance of two rotor-systems aircraft to serve as "flying wind-tunnels" for helicopter research. The aircraft design permits the in-flight testing of full-scale main rotor systems having from two to six blades. The design also allows the addition of fixed wings and thrusting engines that will permit rotor testing at flight speeds up to 550 kilometers per hour. These two aircraft will provide data on aerodynamic problems that are currently mathematically intractable and cannot be solved without the aid of precise flight research results. One research aircraft, with its first set of rotor blades, has completed its first phase of flight testing as a pure helicopter, as a compound with thrusting engines, and as an all-up compound with thrusting engines and augmenting wings. In the next phase, these aircraft will be used to test and optimize the performance of various candidate rotor designs as well as obtain data to improve rotorcraft prediction methodology.

Tilt Rotor Research Aircraft (XV-15). Under a joint Army-NASA contract awarded in 1973, two tilt-rotor research aircraft, the XV-15, were built. The first of the two aircraft has completed full-scale tests which include hover flight and operation under remote control in a wind tunnel. The second XV-15 is presently participating in contractor flight tests to establish the basic flight characteristics for both helicopter and airplane modes of operation. In July 1979, No. 2 XV-15 completed its first in-flight conversion from a helicopter to the airplane mode. It has now flown twenty hours and has reached a true air speed of 204 knots. The Navy joined the program in 1979.

Alternate Fuels Program. The alternate fuels program is part of a long-term coordinated effort among the services, NASA, and the Department of Energy to ensure that liquid fuels obtained from domestic resources such as lower quality petroleum, oil shale, tar sands, and coal will be acceptable alternatives to liquid hydrocarbon fuels in high-performance engines. The initial DoD effort is an experimental program to produce aviation turbine fuels from shale oil and coal. Results to date provide encouraging evidence that the aviation industry can use fuel produced from the vast United States resources of oil shale. In 1979, significant effort was expended developing a Defense Fuels Mobility Action Plan, and a Defense Mobility Fuels Office was established to consolidate the DoD effort.

Technical Development Support. DoD has detailed a number of technically trained persons to NASA to assist in programs of mutual interest. The technological transfer back to DoD in unique functional areas is important. The detailees are working in a variety of operational and R&D programs but most are associated with the Space Transportation System activities which include space mission planning, avionics and communications security, crew procedures, payloads software, logistics, and facilities construction. In 1979, the Air Force assigned a general officer at NASA Headquarters to further strengthen joint Shuttle planning and program implementation activities. At Johnson Space Center (JSC), the Air Force currently has 20 personnel supporting Shuttle activities with growth to 54 people expected by June 1980.

Astronaut Program. The DoD continued to support this program by providing astronaut candidates for the Space Shuttle program. Of 35 new candidates chosen by NASA in 1977, 21 were from DoD. In 1979, these new astronaut selectees completed their training program that began in July 1978. All 21 have been certified and are awaiting assignment to specific payload missions. DoD is also submitting additional candidates for the next astronaut selection by NASA, scheduled for May 1980.



Introduction

The five agencies in the Department of Commerce that contribute directly to the nation's aeronautics and space programs are the National Oceanic and Atmospheric Administration (NOAA), the National Bureau of Standards (NBS), the Maritime Administration (MARAD), the National Telecommunications and Information Administration (NTIA), and the Bureau of the Census (BOC).

NOAA's mission is to improve the safety and quality of life through better comprehension of the Earth's environment and through more efficient use of its resources. To this end, NOAA operates, manages, and improves the nation's operational environmental satellite systems; provides satellite data on the impact of natural factors and human activities on global food and fuel supplies and on environmental quality; uses satellite data and aerial photography for charting, coastal mapping, and geodetic research; employs satellite data to improve the assessment and conservation of marine life; and upgrades weather services by developing new forecasting techniques, automating field operations, and improving dissemination of weather information.

NBS seeks to improve the standards and related services necessary to ensure uniform and reliable measurements. The NBS participation in the nation's aeronautics and space program is to provide measurement support services for space and satellite systems, atmospheric and space research, and aeronautical programs.

MARAD works to improve ship safety, operations, and management. Use of satellites increases the efficiency of commercial ship communication, navigation, and operation.

The NTIA, principal communications advisor to the President, develops and coordinates Executive Branch policy in telecommunications and information. The NTIA is responsible for the management of the radio spectrum assigned for Federal use, explores applications for telecommunications tech-

nology, performs applied scientific and engineering analyses to improve technology, and provides technical assistance to other Federal agencies.

BOC works to improve information on population trends, urban growth, and the internal structure of national land areas. Satellite data are used for demographic studies and population estimates.

Space Systems

Satellite Operations

The National Environmental Satellite Service (NESS) of NOAA operates two satellite systems: the polar-orbiting system and the geostationary system.

Polar-Orbiting Satellites. During the first half of 1979, NESS converted from the Improved Tiros Operational Satellite (ITOS) system to the new generation Tiros-N series. Tiros-N, the NASA prototype and the first of this series, was launched October 13, 1978. NOAA 6, NOAA's first operational satellite of this series, was launched June 27, 1979. These two satellites are known as the Tiros-N system. The Tiros-N and ITOS systems overlapped until July 16, 1979, when NOAA 5, the last of the ITOS series, was deactivated.

Redundancy is achieved in the Tiros-N system by two identical satellites rather than two identical instruments on a single satellite. Tiros-N was launched into a near-polar, Sun-synchronous 870-kilometer orbit crossing the equator in a northward direction at 1500 local time. NOAA 6 orbits at 830 kilometers, crossing the equator in a southward direction at 0730 local time.

The Tiros-N system satellites carry four primary instruments: an Advanced Very High Resolution Radiometer; a Tiros Operational Vertical Sounder, consisting of three complementary sounding instruments, one of which is provided by the United Kingdom; an Argos Data Collection and Platform Location System, which is furnished by France; and a Space Environment Monitor. In addition, the extremely large volume of digital data delivered by

these satellites required installation of a new ground system, which was accepted in February 1979.

Geostationary Satellites. The NOAA designation for its Geostationary Operational Environmental Satellite system is GOES, the successor to NASA's prototype geostationary Synchronous Meteorological Satellites (SMS). Since 1974, two SMS and three GOES satellites have been launched. Presently, Goes 3 and SMS 2 are the operational geostationary satellites covering the Western Hemisphere. SMS 2 is located over the equator at 75° west longitude and Goes 3 at 135° west longitude. SMS 1 (130°W) and Goes 2 (105°W) are on standby status. Goes 1 remained at its position of 56° east longitude over the Indian Ocean. The spacecraft was under control of the European Space Agency until November 30, 1979, to support the Global Weather Experiment. On November 30, 1979, it was commanded to drift eastward at 2° longitude per day. Goes 1 is scheduled to arrive at its destination of 90° west longitude during March 1980.

A new interactive computer system designed to improve the accuracy of the navigation and gridding of GOES images became operational in March 1979. This computer system is called the Visible Infrared Spin Scan Radiometer (VISSR) Interactive Registration and Gridding System (VIRGS). It will provide a faster response time in computing accurate grids on images after normal spacecraft maneuver operations, improve the accuracy of gridded image products, and potentially reduce the amount of costly ground tracking equipment. The more accurate gridding aids in the production and use of "movie loops" which depict cloud motions. These "movie loops" are frequently used for storm warnings such as Hurricanes David and Frederic in August and September 1979 and by TV meteorologists as part of their daily weather programs.

Land Programs. On November 16, 1979, the President designated the Department of Commerce through NOAA to manage all operational civilian remote sensing activities from space [for the text of the President's announcement, see Appendix E]. NOAA's experience in successfully operating and managing three generations of environmental satellites prepares it to assume the responsibility for land remote sensing in addition to its on-going atmospheric and oceanic activities. NOAA will establish and manage an operational satellite program of land remote sensing based upon the NASA-managed Landsat research and development program.

NOAA completed a preliminary plan by December 15, 1979, and will submit a final transition plan to the President by June 1, 1980. Landsat was begun

in 1972 by NASA as a satellite effort specifically designed to test remote sensing techniques for observing surface features of the Earth.

Satellite Data Distribution. During 1979, NESS began upgrading the Satellite Field Services Stations (SFSS) by phasing out their photo laboratories and converting to an all-electronic image displaying system. Electronic processing of satellite images will significantly reduce NESS annual operating costs by more timely production of animated data, improved system flexibility, elimination of photographic laboratory costs, and minimizing equipment complexity. The new satellite image display devices offer low capital investment, low cost for expendables, reliability, unattended operation, consistent good quality imagery, no photo processing, and compatibility with NESS's existing image animation devices.

The GOES Weather Facsimile (WEFAX) Service is now broadcasting data via the geostationary satellites located at 75°W, 105°W, and 135°W. The WEFAX data have been expanded to include standard meteorological charts broadcast from the central satellite in addition to the satellite image transmissions already provided by the east and west satellites. This allows users of the central satellite to have both satellite images and standard meteorological charts. The WEFAX user community has expanded to more than 70 national and international land stations, some of them located in the Caribbean and Central and South American countries, and to over 50 mobile stations carried aboard naval and merchant vessels.

"AM Weather," a new TV weather program produced by the Maryland Center for Public Broadcasting in cooperation with NOAA, the Federal Aviation Administration (FAA), and the Aircraft Owners and Pilots Association, was initiated in 1979. Meteorologists from NESS and the National Weather Service participate in daily (Monday through Friday) 15-minute broadcasts describing the weather over the continental United States. Approximately 200 public television stations across the country transmit the program live. Real-time satellite images and "movie loops" afford an opportunity to show the public where the weather is occurring. This program also is highly beneficial to the aviation and agricultural communities.

The GOES-Tap system, implemented in 1975 to provide for the dissemination of GOES satellite images by geographic sectors, was further expanded in 1979 to include lines to several FAA Air Route Traffic Control Centers. Initial GOES-Tap lines were installed in those centers that control high-density aircraft operations along the east coast. Meteorologists, trained by NESS in weather satellite

image interpretation, are collocated with the FAA controllers and provide them with the latest weather information.

The GOES Data Collection System (DCS) has a total of 41 national and international users that operate more than 1000 Data Collection Platforms (DCP). During 1979, 11 new users and more than 350 platforms were added to the system. A new remote command feature was added to the system; now the user can change the configuration of one or more DCPs in the network by sending a command either by telephone or by satellite directly to the DCS computer which relays the command by satellite to the platforms. This feature saves time and reduces errors inherent in a manual system.

Plans also were completed to develop a GOES DCS Automated Monitoring System which, when it becomes operational in early 1981, will sample the characteristics of the platform radio transmissions. Frequency stability, signal strength, and other performance aspects relating to platform condition can be monitored and automatically recorded as a means of detecting platform malfunction.

Satellite Data Uses

Determining Winds and Temperatures. During 1979, atmospheric temperature soundings and sea-surface temperatures were obtained operationally over the entire globe from the polar-orbiting satellites, and wind measurements were obtained operationally three times each day over the Western Hemisphere from geostationary satellites. Cloud-motion winds were determined at three atmospheric levels at a 300-kilometer spatial interval. These data were provided to the National Weather Service, the United States Air Force and Navy, and twenty foreign governments. In addition, these data become part of the Global Weather Experiment data base.

Digital infrared data from the geostationary satellites are stored in a data base. Real-time users can obtain these data to supplement conventional observations. Satellite-derived cloud-top temperatures and land temperatures provide an instantaneous view of conditions associated with the development, intensity, and surface coverage of convective storms. These observations are used in determining the potential for the development of damaging winds and flash flood events. Land-surface temperature patterns are used to determine the potential for frost or freeze conditions threatening agriculture, and the sea-surface temperature patterns are used to assist the fishing industry and route ships in major ocean current regions. This improves the efficiency of operations at sea for two major users.

During 1979 NESS implemented a program to compare information on cloud-motion derived winds from geostationary satellites operated by the United States, the Japanese Meteorological Satellite Center, and the European Space Agency. These studies included special data sets produced by the Space Science and Engineering Center at the University of Wisconsin and two research laboratories in Europe. This year's comparisons coincided with the Global Weather Experiment Intensive Observation Periods of January and May 1979. The results so far show that observations from these diverse sources are quite compatible. Two comparison periods each year are to be continued indefinitely to ensure accuracy and compatibility of these data for the World Weather Watch.

The NOAA Wave Propagation Laboratory (WPL) completed the second phase of a systems analysis on the feasibility of measuring the global winds with a satellite-borne lidar (laser-light-detection-and-ranging system). The technique involves the tracking of dust and other particles suspended in the atmosphere. The attenuating effects of typical cloud distributions, ranging from fair weather cumulus to intertropical convergence zone clouds, were added to the study in this past year. The failure of the laser beams to penetrate thick, water-droplet clouds resulted in some loss in accuracy at pressure levels below 700 millibars, but in most cases wind speed could be determined to within 2 meters per second in the presence of clouds, and better than 1 meter per second in the clear air.

Computer programs were successfully developed for various man-machine interactive methods to process and evaluate Tiros-N temperature and moisture soundings. Comparisons made between satellite-derived temperatures and radiosonde temperatures showed Root Mean Square errors of about $\pm 2^{\circ}\text{C}$ at most levels. Many case studies were conducted integrating the Tiros-N temperature data with geostationary satellite cloud-cover images and radiosonde observations. Data sets were collected and processed for regional forecast studies by groups at the Australian Numerical Meteorological Research Centre and the United States National Center for Atmospheric Research. One case study included an orbit over tornadoes in the United States on May 2, 1979. In this study, detailed analyses made of the Tiros-N data 12 hours prior to the tornado development along the Oklahoma-Kansas border detected the low pressure area, the intense moisture front with convectively unstable air, and the strong divergence of the upper level jet over the area where the severe weather subsequently occurred. Thus, the Tiros-N data were able to de-

lineate the precursor conditions of severe weather development.

Geostationary-satellite-derived winds often were obtained simultaneously with Tiros-N overpasses. The capability was developed to use Tiros-N soundings to assign pressure heights to these winds. Evaluations suggest that the cloud-height determination is considerably improved by merging these data sources. This procedure was used at the University of Wisconsin to determine cloud heights from Goes 1-derived winds over the Indian Ocean during the Global Weather Experiment.

Monitoring Global Radiation. Radiation budget data were derived from the Tiros-N Advanced Very High Resolution Radiometer beginning January 1, 1979. Data from the Tiros-N satellites, like the ITOS series, include measurements from which various heat budget components are derived and mapped globally on different time scales. These heat budget components are important diagnostic tools for meteorological and climatic studies and a source of information to the growing number of scientists interested in climate fluctuations. These data also provide information on the radiative régimes of the Earth, and they yield indirect evidence on variations in cloudiness, ice and snow cover, and other heat sources.

The Earth Radiation Budget (ERB) experiment, carried on Nimbus 7 (launched October 24, 1978), continued to monitor solar output during 1979. The derived solar constant remained at a value of 1376 watts per square meter. The ERB experiment, by observing in detail both incoming and outgoing radiation, will provide accurate information on the Earth's radiation budget as a function of location and time.

Environmental Warning Services. On selected days from March through June 1979, NESS operated GOES satellites in a special three-minute-interval imaging mode to support the Severe Environmental Storms and Mesoscale Experiment (SESAME). The objective of Sesame is to use a combined set of satellite and conventional observations to allow meteorologists, for the first time, to observe convective cloud and storm development with a resolution in space and time comparable to the scales of the atmospheric phenomena being observed. Meteorologists are trying to determine the fine-scale, short-lived mechanisms that trigger thunderstorms and thunderstorm systems which produce hail, tornadoes, and damaging winds. Additional support consisted of communications services and the provision of the new electronic satellite image video display system. This system was placed at NOAA's National Severe Storms Laboratory, Norman, Oklahoma, for use by the researchers.

In addition to being the first integrated use of satellite data, this also was the first field use of an electronic satellite image animation device. The benefits of satellite data and satellite image animation to the research were convincingly demonstrated on April 10, 1979, when tornadoes along the Red River Valley devastated the towns of Vernon and Wichita Falls, Texas, and Lawton, Oklahoma. Satellite data called attention to this threat and allowed forecasters to sound an early alert, thus preventing the possibility for further loss of lives and property. The data from Project Sesame are currently being analyzed.

NESS's Satellite Field Services Stations (SFSS) were instrumental in many new environmental warning activities during 1979. One of the primary functions of the SFSS is to support the National Weather Service (NWS) by providing interpretation of GOES images to improve the accuracy of routine forecasts and to provide timely severe weather warnings to the public.

In response to a demonstrated need to improve marine and coastal weather services in the Gulf of Mexico, a Gulf of Mexico satellite support unit was staffed in June 1979 and located with the Kansas City SFSS. In 1980, the "Gulf Support Unit" will be moved to Slidell, Louisiana and will be collocated with the NWS Forecast Office.

In 1979, NESS's Synoptic Analysis Branch placed into operation a procedure for estimating precipitation intensities from GOES satellite images. These precipitation estimates were provided as input to the NWS forecasts of possible flash-flood events. The most notable event for which rainfall estimates were provided was the Pearl River flood in Mississippi. Rainfall estimates also are provided for the International Water Commission (United States and Mexico) and are useful for planning the regulation of water flow in the Rio Grande River.

In research, infrared measurements from geostationary satellites continued to be used in a statistical approach to measuring rainfall for input to the NWS river-flow models. While a correlation was found between infrared cloud-top temperatures and rainfall, results were improved by adding other meteorological variables derived from a combination of satellite measurements and conventional observations. Testing the repeatability of these relationships under various meteorological conditions continues.

NOAA's National Hurricane and Experimental Meteorology Laboratory has continued to use satellite data for its research into hurricanes and convective cloud systems. Satellite data were collected over Hurricanes David and Frederic as these storms passed over Hispaniola, Cuba, and the United

States. Simultaneous data also were collected by NOAA's research aircraft. Aircraft data included low-level wind fields, storm intensities, and digitized radar depicting the rain distributions with time. Aircraft and satellite data sets will be used to study the degree to which cloud motions represent winds at the lower levels, the accuracy of storm intensity estimates from satellites when compared with observed values, the accuracy and detail of rainfall estimates from satellite images when compared with quantitative airborne radar measurements, the possible indications of diurnal variations in the satellite-observed cloud field when compared with radar observations and observed wind fields, and forecast changes in storm intensity and motion from satellite-observed cloud characteristics by comparison to the research aircraft measurements. Wind fields have been determined from cloud motion in the outer fringes of hurricanes but not within the inner core of the storm. Rainfall estimates from satellite images seem to give reasonable results, but quantitative comparisons over lengthy periods of time have not been possible because of little surface truth data. An accumulation of digitized radar measurements over long periods will provide data for these comparisons. Satellite storm-intensity estimates have been reasonably good, but large errors are occasionally found. Further study of the satellite and concomitant aircraft data should provide more reliable comparisons.

The Navy-NOAA Joint Ice Center became operational in June 1979. The Alaskan and Hemispheric Ice Analyses are now produced at the Joint Ice Center at Fleet Weather Facility, Suitland, Maryland. These ice charts are an important aid to shipping companies that resupply Arctic ports. The companies can route their ships to avoid severe ice conditions, reducing the risk of damage and reducing the costs in time and fuel.

During 1979, the Anchorage SFSS expanded its operation to provide 24-hour service to Alaska. A new technique to forecast the intensification of storm systems in the mid-Pacific and Gulf of Alaska was operationally tested. Because of the limitations of numerical forecasting over the oceans, it is often difficult to locate, track, and forecast the development of storms in the mid-Pacific. This technique, developed at the Anchorage SFSS, uses satellite data to locate and provide a quantitative estimate of the central pressure that can be used by NWS forecasters to estimate storm severity and issue weather and gale warnings. Of 81 operational cases, the SFSS surface pressure forecast guidance averaged 1.28 millibars lower than the observed value; the numerical predictions of central pressures averaged 15 to 19 millibars higher than observed values.

Cloud images of the western Pacific Ocean from Japan's Geostationary Meteorological Satellite are now available to forecasters at Honolulu and the National Meteorological Center. These pictures cover a large area of the Pacific not viewed by United States geostationary satellites; and they are an important addition to observing upstream weather conditions over the open ocean.

In 1979 an operational program was started to measure natural passive gamma radiation by flying instrumented aircraft over selected areas of the north-central Plains. This radiation information is used to help estimate water content of snow cover. When used with satellite information on the areal extent of snow cover, NWS has a powerful new tool to better judge the threat of flooding from snowmelt.

Determining Ocean Conditions. The NOAA Seasat program was subjected to an intensive review immediately following the satellite's demise on October 9, 1978. Adjustments were made in the planned experiment program to account for certain data which could not be collected. The result was cancellation of certain experiments. Major emphasis was directed toward the surface truth areas where concurrent ship, aircraft, and satellite data were collected during the 99-day Seasat lifetime. These were the NOAA-coordinated Gulf of Alaska Seasat Experiment, the Joint Air Sea Interaction experiment, oceanic tropical and extratropical storms, Gulf Stream, polar ice and other areas where significant surface truth was available.

During its period of operation Seasat covered most of the 1978 tropical storms. It made 126 passes over 21 hurricanes and typhoons, 179 passes over 20 tropical storms, and 64 passes over tropical depressions. Seasat radar images were compared with coincident surface observations made by NOAA during the Gulf of Alaska experiment. The results indicate that satellite-borne imaging radars are extremely valuable tools in the study of ocean surface and internal waves, surface currents, and mesoscale atmospheric disturbances.

NOAA's Pacific Marine Environmental Laboratory (PMEL) provided the meteorological analysis of conventional surface observations for comparison with Seasat scatterometer wind fields. The scatterometer potentially is a useful tool for operational meteorology because it can accurately locate low pressure centers, storm producing regions, and zonal bands of high winds.

NOAA's National Hurricane and Experimental Meteorology Laboratory evaluated the usefulness of satellite-sensed surface observations in the vicinity of hurricanes to provide information concerning the areal extent of hurricane and gale force winds

and to provide initial data to hurricane forecast models and storm surge models. Data gathered during the 1978 hurricane season by the Seasat microwave scatterometer system have been used in this study. Preliminary results indicate that the satellite surface wind speeds, below gale force, are overestimated by about 15 percent. Although winds in the hurricane's inner core are not well resolved, this method of remote sensing offers great potential in obtaining a snapshot of the hurricane wind field.

NOAA's Wave Propagation Laboratory developed a computer program for estimating significant waveheight and mean sea level using Seasat radar altimeter data. Comparisons with sources of surface truth show agreement for significant waveheights up to 30 centimeters. PMEL and Geodetic Research and Development Laboratory investigators completed the first definitive baseline experiment comparing satellite-altimeter-derived ocean surface topography with shipboard observations. Results show that the satellite altimeter can measure surface topography within 10 centimeters of that measured with standard shipboard oceanographic measurements.

In 1979, two major oceanographic cruises were conducted to obtain surface truth data to support the Nimbus 7 Coastal Zone Color Scanner (CZCS) experiments. The first cruise was conducted in March 1979 in the Gulf of California, and the second cruise was conducted in May and June 1979 in the northwest Atlantic. The cruises were supplemented by two field trips to Bermuda to obtain atmospheric transmittance measurements. Optical and biological measurements were obtained from a wide range of water masses by scientists from NESS, PMEL, Scripps Institution of Oceanography, University of Southern California, University of Miami, and San Jose State College. Results from these cruises provide the first comparisons between remotely sensed ocean color from the CZCS, surface-measured ocean color, and the distribution of suspended particulate matter, especially that associated with biological activity.

The Gulf Stream Analysis, which began in 1973, continued to be produced in 1979. Based on high-resolution infrared images from the Tiros-N and GOES satellites, the weekly composite map shows the location of the Gulf Stream, warm and cold eddies, and the thermal interface between the slope and shelf waters. Since fish congregate at thermal boundaries, fishermen use these charts to locate productive fishing grounds. A related product which describes only the north or west boundary of the Gulf Stream also was produced three times a week. The Gulf Stream Wall Bulletin, broadcast

twice daily over Coast Guard radio, gives a sequence of points that represent the west or north wall of the Gulf Stream. Coastal shipping interests used this information to route their ships to take advantage of the ocean currents.

A tri-agency group conducted a study related to the development of a National Oceanic Satellite System (NOSS) and formally published its findings in March 1979. This group, with representation from Commerce, NASA, and Defense, focused on the operational needs of the civil and defense communities requiring oceanographic information, and on the space and ground system that would be necessary to satisfy those needs. NOSS would provide a limited operational demonstration of the ability of satellites to sense oceanic phenomena.

Determining Lake Conditions. The Great Lakes Ice Analysis was produced twice weekly during the ice season from January through April 1979. Visible high-resolution satellite images from both the Tiros-N and GOES satellites were used to analyze the ice conditions in the lakes. Ice conditions were very severe during the second half of February. Between February 17-22, 1979, all five Great Lakes were completely frozen except for a small area in southwestern Lake Ontario and an area in central Lake Michigan. These analyses provide information to ships navigating this vital waterway.

Determining Hydrological Conditions. Elements of NOAA, NASA, and the Department of Agriculture cooperated in conducting two soil moisture field missions at the Luverne, Minnesota, hydrologic test site in November 1978 and June 1979. Although the ground data sets have been processed, aircraft and satellite measurements have not yet been received. A nuclear-powered, combination snow-water-equivalent and soil-moisture gage was installed, and a Data Collection Platform will be modified to transmit the data through the GOES Data Collection System.

NESS continued operational snowmapping from satellite data for thirty river basins in the United States and Canada. Snowcover during the 1978-1979 winter season was found to be slightly below average in the Pacific Northwest, average in California's Sierra Nevada, and above average in the mountains of Arizona, Colorado, and Wyoming. Snowmapping of the Missouri River basin (40,700 square kilometers) above Helena, Montana, was begun during the 1978-1979 season at the request of the Department of Agriculture's Soil Conservation Service and the National Weather Service. Also, weekly satellite-derived snow maps for Afghanistan and neighboring Himalayan nations were begun in April 1979 at the request of Agriculture's Joint Agricultural Weather Facility.

The National Bureau of Standards has studied the electromagnetic scattering properties of snowpacks to provide technical data to NASA to develop new sensor systems for earth observation applications.

Monitoring Agricultural Conditions. A new program was initiated by NESS in 1979 to provide dedicated support to NWS agricultural meteorologists in the states of Oregon, Washington, California, and Arizona. Satellite data are used to improve frost forecasts to prevent crop loss. Detailed analyses of satellite data from polar-orbiting and geostationary satellites are made and disseminated to the agricultural meteorologists who are in direct contact with the fruit growers. These analyses incorporate cloud cover, movement of clouds, and changes of intensity of clouds on a mesoscale in areas of concentrated agricultural activity. Further research is being conducted to correlate satellite-derived temperature and ground-moisture-level measurements with surface-observed data so that future satellite analyses may be used to reveal actual readings. These readings will be used to establish the probability of frost with sufficient lead time to allow producers to take preventive measures to protect crops.

From November 1974 until November 1978, NOAA, U.S. Department of Agriculture, and NASA cooperated in a Large Area Crop Inventory Experiment (IACIE). The purpose of IACIE was to determine if satellite crop monitoring and meteorological observations could be used with climate and crop-yield models to make timely and accurate estimates of future crop production in the major wheat-producing countries of the world.

AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing) is a new project that began in 1979. AgRISTARS is a cooperative research effort among five Federal agencies—Departments of Commerce, Agriculture, and Interior, Agency for International Development, and NASA. The objectives of AgRISTARS are to develop an early warning system able to detect conditions affecting crop production and quality and to provide techniques for more accurate forecasts of domestic and foreign commodity production. The AgRISTARS effort will develop and test techniques using advanced remote sensing data obtained from NOAA and NASA satellites and selected remote-sensing data from aircraft. While the potentially most valuable return of AgRISTARS research will accrue from improved information concerning foreign crop production, domestic agriculture information also will be useful. Satellite data should mean better commodity information at the county and regional level.

Fisheries Monitoring. During 1979, NESS began issuing surface temperature maps of the ocean

waters adjacent to Alaska. High-resolution infrared digital data from Tiros-N are used. Analyses are prepared weekly for cloudfree areas, and they are distributed to 35 locations by the National Weather Service Alaskan facsimile network. The maps also are mailed to 25 other subscribers. Since the behavior of the sea surface temperature field of Alaskan waters is relatively unknown, these maps allow researchers, commercial fishermen, and state and Federal management personnel to study and correlate fish catch statistics. Since the salmon, halibut, and crab fisheries are the economic backbone of most of coastal Alaska, the value and support of this product among commercial and recreational fishermen continues to grow.

The National Fisheries Engineering Laboratory (NFEI), the National Weather Service, and NASA are cooperating to develop a small portable satellite communications terminal for the use of government observers stationed on foreign and domestic fishing vessels within the U.S. Fisheries Conservation and Management Zone (320-kilometer limit). This will provide the observer with a means to relay weather data, catch, position, and other information to the land on a nearly real-time basis.

The prototype Marine Mammal Transmitter developed for tracking porpoise using the Nimbus 7 Random Access Management System was tested in 1979. Field tests of the instrument were conducted in Hawaiian waters by attaching transmitters to Hawaiian spotted dolphins and observing their movement. If these experiments are successful, operational units will be procured for further tagging experiments in 1980.

NFEI has modified its effort to measure ocean surface circulation using scatterometer data because of the loss of Seasat. An experiment to determine surface layer transport in the Gulf of Mexico is being conducted. Bathythermograph data will be combined with coastal circulation and open ocean models to develop a complete interactive display of the Gulf of Mexico's circulation. A grid of 78 stations has been established to determine continental shelf circulation in homogeneous water masses to provide insight into the expected sea-level response to various wind fields. Menhaden and shrimp data are being obtained to correlate with these models. The first implementation of the coastal circulation model for Gulf waters adjacent to Louisiana and Texas has been completed, showing a correlation between water circulation and shrimp yield.

Environmental Monitoring Using Data Buoys. In 1979, the NOAA Data Buoy Office converted all 22 of its data buoys to transmit environmental and communications data through the GOES satellites. Some buoys were relocated to provide maximum

coverage of the most critical data-sparse marine areas. Six buoys are located in the Northeast Pacific and Gulf of Alaska, four are located in the Gulf of Mexico, ten are located in the Atlantic, and two are located in a new Great Lakes data buoy network. The Great Lakes network will be expanded to eight buoys over the next two years. Plans are also underway to incorporate the 12 Coast Guard large navigational buoys, located at the sites of former lightships, into the GOES Data Collection System. A prototype system now is in operation on the Columbia River Bar Navigational Buoy. Both the data buoys and the navigational buoys provide meteorological data and surface water temperatures. Subsurface water temperatures and wave data are obtained from selected buoys. These data are used by the National Weather Service for forecasting and storm warning, by the Bureau of Land Management for continental shelf assessment, and by various scientific programs with specialized marine data requirements. All moored buoys are equipped with position-fixing systems which permit the Nimbus or Tiros-N satellite to locate them when they go adrift. Most buoys have been modified to use the Tiros-N Argos Data Collection System for position fixing.

Other Uses of Satellites and Space

International Cooperation

Global Weather Experiment. During the Operational Year (December 1, 1978 to November 30, 1979), NESS has archived satellite-derived observations of cloud-motion vectors, sea surface temperatures, and vertical temperature profiles on magnetic tapes that are sent to the Special Observing Data Centre in Sweden. Approximately 40,000 cloud motion vectors per-month are derived from the GOES east and west satellites. About 1 million sea-surface temperatures and 40,000 atmospheric temperature soundings per month are obtained from the Tiros-N satellite. The European Space Agency provided the control and data handling functions of Goes 1, located over the Indian Ocean. The University of Wisconsin processed Goes 1 data to obtain wind fields over this area. The quantity and quality of satellite-derived meteorological observations are expected to greatly enhance the utility of the final data base obtained from the Global Weather Experiment. These data will be used in global atmospheric modeling research.

Sharing Data. More than 120 countries now avail themselves of the medium-resolution Automatic Picture Transmission services provided by the

polar-orbiting Tiros-N system satellites, and at least 16 countries now have the capability to receive High Resolution Picture Transmissions and Direct Sounder Broadcasts from which atmospheric temperature/humidity profiles may be generated. While the primary applications of these direct readout transmissions are in storm detection and aviation forecasting, these satellite observations also are supporting special hydrologic, oceanographic, agricultural, and other operational and research programs overseas. Sea-ice reconnaissance, snow accumulation and melt, agricultural weather forecasts, locust control activities, and pelagic fish migration and harvesting are among the many activities being supported by direct readout of satellite data.

Environmental Satellite Assessments. Precipitation estimates from Tiros-N and GOES satellite images are used by the Environmental Data and Information Service to directly support the Department of State's Agency for International Development (AID) disaster assistance effort. These assessments evaluate the effects of weather variables on crops in the developing nations of Africa, Southeast Asia, and the Caribbean basin, alerting AID of potential droughts, floods, and other weather-induced natural disasters. This support has enabled earlier shipments of food and improved efficiency in planning and implementing emergency operations.

Domestic Activities

Demographic Studies. The Census Bureau is using Landsat data to update its statistics on land and water areas of the United States for the 1980 Decennial Census. Digitized county boundaries are being fitted to screen-displayed Landsat images, and through interactive processing, land is separated from water. Area measurements are then extracted for both of these surfaces. This new technique is considerably more accurate and cost-effective than the conventional methods used in past census operations.

Landsat data also are being studied for a possible future census application under the terms of a NASA Applications Pilot Test agreement. In 1979, investigations tested the use of computer-processed Landsat data for showing land-cover changes and delineating urban zones around two sample metropolitan areas. Digital registration has been accomplished for Landsat scenes over several different years, and these are being processed to show any significant land-cover change. The results will be compared with interpreted changes detected on aircraft photography for the same time period.

Determination of the Earth's Shape and Gravity Field

The National Ocean Survey (NOS), as a part of its mission to maintain a network of accurately positioned ground stations for geodetic surveying and mapping, continues its work with NASA to evaluate applications of space systems to geodesy and geodynamics. In its continuing investigations into Very Long Baseline Interferometry (VLBI), a system based on interferometric observations of extragalactic radio sources, NOS is establishing a network of three observatories to regularly monitor polar motion and universal time. Two of the three required stations, located near Ft. Davis, Texas, and Westford, Massachusetts, are scheduled for test operations in 1980. This network should be capable of determining polar motion to ± 10 centimeters and universal time to ± 0.1 millisecond over 8 hours. NOS continues to collect satellite Doppler data for precise positioning to compare with other newly developed space technology, such as lunar laser ranging, satellite laser ranging, and VLBI. Satellite Doppler data also are used as inputs to the model of the Earth being refined by the Doppler orbital computations in the international polar motion experiment.

Studies of ways in which the signals from the Global Positioning System (GPS) satellites can be used to measure crustal movement and in general surveying requirements are being carried out by the National Bureau of Standards (NBS), the Jet Propulsion Laboratory, the Naval Surface Weapons Center, a joint Massachusetts Institute of Technology-Draper Laboratories group, and the National Geodetic Survey. The work at Geodetic Survey and NBS has shown theoretically that phase-difference measurements on signals reconstructed from the incoming GPS signals are capable of accurately determining the baseline between the receivers with only two hours of observations per site.

NOS also published a new global model for the Earth's gravity field based on the density layer method. Altimeter observations from the Geodynamics Experimental Ocean Satellite (Geos 3) and gravity, Doppler, and satellite triangulation data were used. NOS began an analysis of altimeter data from Seasat and provided assistance to the Jet Propulsion Laboratory in preparing data reduction programs. Altimeter data have been used to obtain elevation variations over land. NOS also prepared a study on Gravsat, a proposed pair of low-altitude satellites that sense high-frequency variations in the gravity field. This study confirmed that at an altitude of 200 kilometers the system can recover gravity data within 3 milligals over one-degree blocks.

Satellite Communications

Public Service Satellites. The National Telecommunications and Information Administration (NTIA) was instructed through the President's National Civil Space Policy to stimulate the aggregation of potential public service users of communications satellite services, drawing on technology already in existence, and to work with the Agency for International Development and the Department of Interior in translating domestic experience in public service programs into programs for less developed countries and remote territories. The Interagency Committee on Satellite Telecommunications Applications (ICSTA), chaired by NTIA and representing 18 Federal agencies, has brought about progress in the first of these three missions, market aggregation. With ICSTA guidance and support an operational public service satellite and cable television network began service in October 1979. Initially offering 22.5 hours a week of accredited college courses and other public services to residents and educational agencies in Appalachia, in 1980 this network will extend its services nationwide.

In fulfilling its international mission in public service satellites, NTIA has established collaborative relationships with the Agency for International Development (AID) and the Department of the Interior. The support is designed to provide basic telephone and broadcast programming to remote areas of lesser developed countries via communications satellites.

Technical Support Activity. NTIA's Institute for Telecommunications Sciences (ITS) is currently undertaking a series of studies to investigate the potential impact of the operation of the envisioned Satellite Power System (SPS) upon the ionosphere and telecommunications systems. SPS would be a geostationary satellite system with solar collectors and is one of a number of alternative energy sources under investigation by the Department of Energy. The system would involve the transfer of solar energy from geostationary satellites to the surface of the Earth. This energy transfer could lead to substantial heating of the ionosphere which could adversely affect the performance of telecommunications systems.

ITS has reviewed the GOES satellite certification standards and recommended some revision to NOAA that are necessary since the GOES Data Collection System will be integrated into a worldwide network. ITS also witnessed certification tests at two private contracting companies who have developed new Data Collection Platform radio sets for use by local, state, and federal agencies.

International Communications Policy. NTIA's Office of International Affairs participates in the

development of international satellite policies and agreements. In addition to the traditional oversight that NTIA exercises over Comsat's INTELSAT activities, responsibilities pertinent to Comsat's participation in the International Maritime Satellite Organization (INMARSAT) also were assumed by the agency. NTIA ensures that Comsat does not participate in a manner contradictory to U.S. telecommunications policy.

NTIA has continued its role as monitor and coordinator of the government's use of the radio-frequency spectrum. In that capacity, ITS—through participation with the International Radio Consultative Committee, an agency of the International Telecommunications Union, and the Interdepartment Radio Advisory Committee—contributed to the preparation of the United States position relating to satellite communications for the 1979 General World Administrative Radio Conference.

Commercial Satellite Service. The International Maritime Satellite (INMARSAT) Organization was implemented in 1979 by a commitment of funds from participating countries or entities. The Comsat General Corporation has been designated in law to be the United States entity in INMARSAT. The U.S. Maritime Administration and the Coast Guard are working with Comsat to define appropriate safety services for incorporation into INMARSAT.

The Maritime Administration successfully concluded its research and development program that provided computer-assisted fleet management through Maritime Satellite (MARISAT) communications to ten U.S.-flag ocean carrier companies. This effort provides a satellite communications network that links the corporate offices of the shipping companies directly with the ships. Future efforts will focus on the further development of shipboard management information needs and requirements that will provide the framework for INMARSAT utilization.

Satellite Frequencies. The feasibility of using the Orbiting Standards Platform (OSP) satellite to accurately measure radiated fields and antenna properties of satellite communication links and components has been investigated jointly by the National Bureau of Standards (NBS), NASA's Goddard Space Flight Center, the Institute of Telecommunications Sciences, and Comsat Laboratories. Heavy use of the electromagnetic spectrum in the geostationary orbit has increased interference between different satellite systems and is providing the impetus for extensive frequency reuse. For this reason, and because of higher investment costs of satellite replacement and new satellite deployment, it was found that a standards satellite would serve a unique and cost-effective function in making crit-

ical measurements on geostationary satellites before and after launch.

Satellite Time Service. Distribution of National Bureau of Standards (NBS)-referenced time code at 468 MHz from two of NOAA's Goes satellites was continued and improved during 1979. An NBS-developed instrumentation system was installed at NOAA's Command and Data Acquisition station, Wallops, Virginia. The new system provides more reliable and stable timing signals for a variety of applications in navigation, communications, electric power network operations, and scientific data monitoring throughout the Western Hemisphere.

Space Support Activities

Measurement and Calibration Services

The National Bureau of Standards (NBS) is providing calibrations and standards to support the Space Shuttle program. This has included development of standards for near and vacuum ultraviolet primary and transfer sources, including new instruments for direct inflight calibrations, for solar physics radiometry; construction of an instrument for the determination of ozone cross-section data; development of research standards for halocarbons and nitrous oxide; and development of a chamber to calibrate vacuum ultraviolet spectrometers.

NBS has provided radiation data for space shielding requirements. The longer duration of present and planned satellite missions and the increasing use of radiation-sensitive metal-oxide, semiconductor devices make it important to have accurate estimates of radiation dose levels inside spacecraft.

Applications of Space to Science and Technology

In preparation for the Space Shuttle program, NBS is investigating fundamental measurement problems which may be studied in the micro-gravity environment of space. These include the mechanisms through which gravity interferes with nearly all measurements of equilibrium properties of fluids close to the liquid-vapor critical point; methods for control of convection effects during alloy solidification, including expected effects from micro-gravity; and methods for determining the thermophysical properties of reactive materials by use of containerless techniques possible in space.

Experimental and theoretical studies are being carried out, as part of NASA's Lewis Research Center's Space Shuttle combustion research program, to determine the effects of gravity on flame inhibition by halogens. Improved understanding of combustion mechanisms will provide information

needed to better define the application of halocarbons as flame inhibitors both in the Space Shuttle and terrestrial environments.

Solar Activity

The International Solar Maximum Year (ISMY) program, began in August 1979, will continue through February 1981. This period coincides with the solar cycle maximum (sunspot surge). Constellations of satellites poised around the Sun and Earth will record detailed development of active regions on the solar surface, and arrays of Earth-surface solar observatories will coordinate their viewing of the growth of these regions. In particular, scientists with experiments on board the Solar Maximum Mission satellite, to be launched in early 1980, are receiving support from a Space Environment Services Center (SESC) unit established at Goddard Space Flight Center. Data from the Tiros-N and the three International Sun-Earth Explorer satellites will be available for operational use by SESC in late 1980.

Space and Atmospheric Research

Space Physics

Interplanetary Physics. The effect of coronal mass motion, initiated by solar flares and other transient disturbances on the Sun, was examined by NOAA's Space Environment Laboratory (SEL) in cooperation with the NASA Marshall Space Flight Center, the Harvard College Observatory, and the University of Alabama, Huntsville. Major features of coronal transient events, such as their expanding bubble-like characteristics and the development of shock waves, were successfully described by theoretical computer simulations. Additional studies have been made on multi-dimensional, time-dependent simulations of the interplanetary consequences of these solar disturbances.

Magnetospheric Physics. Significant advances in the understanding of the dynamics of the ring current (produced by geomagnetically trapped charged particles comprising the Van Allen radioactive belts) have been made by SEL scientists. Following earlier laboratory studies defining the importance of ions heavier than hydrogen, further study has indicated an important aspect of ring current enhancement during geomagnetic disturbances. A physically consistent theory of the production of magnetospheric electric fields responsible for the acceleration of auroral electrons has been formulated.

The comprehensive data base provided by the two International Sun-Earth Explorer satellites now extends over more than a year, providing long time, spatial, and energy resolution data throughout the region surrounding the Earth out to its approximate apogee of 21 Earth radii. Analysis techniques have been developed which enable the motion of the magnetospheric boundary to be determined near satellite crossing. A wave structure also has been found on that boundary which provides information on the nature of the interaction and momentum and energy transfer from the solar wind into the magnetosphere. The coupling of the solar wind and the magnetosphere and the explosive energization of charged particles in the magnetospheric tail—responsible for auroral precipitation of energetic particles and for magnetospheric substorms—are crucial to the understanding of the global dynamics of the magnetosphere.

Stellar Atmospheres. The National Bureau of Standards (NBS) has been developing the absolute radiometric calibration techniques and the spectroscopic analysis methods for reliable measurement of physical properties (temperatures, densities, velocities, and magnetic fields) in solar and stellar plasmas. Using data obtained from the Copernicus and International Ultraviolet Explorer satellites, NBS is applying these methods to the analysis of ultraviolet spectra from the quiescent and flaring chromospheres of single and close binary stars cooler than the Sun. X-ray observations with the High Energy Astronomy Observatories (HEAO 1 and 2) are being used to model the hot coronae in stars cooler than the Sun and to study stellar flares.

Aeronautical Programs

Aeronautical Charting

The National Ocean Survey (NOS), which publishes and distributes the nation's domestic aeronautical charts, has developed a new bound-volume format for Instrument Approach Procedure Charts (IAPCs). These charts portray all aeronautical data required to make an instrument approach to airports in the contiguous United States, Puerto Rico, and the Virgin Islands. This replaces the traditional loose-leaf volume which pilots had to manually update every 14 days. NOS now issues 15 bound volumes containing all current Federal Aviation Administration (FAA)-approved IAPCs every 56 days. Changes in procedures, within the publication cycle, are issued in a single-volume at the 28-day mid point of the cycle. The next 56-day issue incorporates these changes and replaces all preceding volumes.

The expanded use of the National Airspace System has increased the demand for more controlled airspace and for applicable aeronautical charts and services. At the request of the FAA, NOS began development of 20 Minimum Instrument Flight Rule (IFR) Altitude Sector Charts, which provide air traffic controllers with minimum IFR altitude information for radar vectoring and off-airway operations. NOS also has compiled a special-use Terminal Area Control Chart for the Saranac Lake, New York, area to accommodate the heavy air traffic expected for the 1980 Winter Olympics.

Safety Services

The National Bureau of Standards (NBS) has developed a modulation factor standard to support the FAA's Instrument Landing System (ILS), which provides landing guidance to aircraft when visual guidance is not available. The NBS standard furnishes the highly accurate (within 0.2 percent) test signals for calibrating the FAA's electronic instruments that are used to install and maintain ILS apparatus at airports. It will be used by avionics manufacturers and commercial and private carriers to ensure correct operation of on-board instruments. NBS also has developed phase-angle standards for the calibration of test equipment for the VOR navigation system.

Forecast Guidance

The NWS National Meteorological Center (NMC) developed several forecast models to provide improved forecasts basic to safe and economic aircraft operations. During 1979 an optimum interpolation scheme was developed that updates the models by incorporating winds and temperatures measured from high altitude jet aircraft along standard routes. In addition, global synoptic stratospheric analyses and predictions have enabled NMC

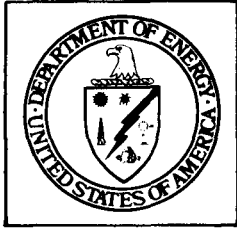
to provide valuable support to the ozone monitoring program. Studies are being conducted to determine the effects of cabin ozone on passengers and crews of stratospheric flights.

Automation of Airways Observations

NWS, in cooperation with the FAA, has developed a system to measure automatically surface wind and altimeter settings and to generate a voice report which is automatically transmitted to the pilot through aeronautical navigation aids. The prototype of this device, called Wind, Altimeter, and Voice (WAVE), is being tested at Frederick, Maryland. Automated weather observations have been made more complete by the addition of new cloud ceiling and visibility measuring equipment at airports. Seven of the new improved automatic observation stations were installed during 1979, as well as 16 remote, unmanned, automatic weather observation stations. Weather information from the latter two types of automatic observing stations is not transmitted directly to pilots but is added to the national aviation weather reporting system and used by forecasters to monitor rapid weather changes.

Automated Route Forecasts

NWS is cooperating with the FAA to develop a system to provide automated route forecasts to pilots. This is a large effort that requires the development of a new data base of objective weather information. Operationally, this grid data base would be computer-searched to provide specific route forecasts which could be delivered to the pilot by machine-generated voice. Important to this new system is the development of a forecaster-computer interface so the data base can be continually updated.



Introduction

Since the early 1960s, the Department of Energy (DOE) and its predecessor agencies have dedicated their specialized skills to the support of the United States space program. The earliest Navy navigation satellite, launched in 1961, delivered a mere 2.7 watts of electric power derived from the decay heat of the radioisotope plutonium-238 acting upon thermoelectric couples carried by the 2.3-kilogram unit. By contrast, the most recent outer planetary spacecraft launched by NASA in August-September 1977 each carried three multi-hundred watt generators supplying a total of 475 watts of electric power. The dramatic photographs transmitted from Voyagers 1 and 2, revealing hitherto unknown details of the topography of Jupiter and its moons, were possible only through the use of such space nuclear power systems. Continuing progress is being made in the directions of compactness, lighter weight, and improved efficiency and safety.

Progress in Space Applications of Nuclear Power

DOE provides substantial support to the U.S. space program through its technology development and production efforts on nuclear-powered electric generators for current and potential NASA and DoD missions.

Radioisotope Thermoelectric Generators (RTGs)

To achieve a state of readiness for the increasingly rigorous demands for safety and performance, continuing progress must be made at many points along the frontier of technology. During 1979, the multi-hundred watt generator, already performing yeoman service on DoD's Lincoln Experimental Satellites and on board the Voyager 1 and 2 outer planetary spacecraft, was upgraded by selection of an improved iridium-tungsten alloy for the fuel capsules and by application of composite fiber graphites in the heat source aeroshell. The more ductile and thermally stable iridium capsule mate-

rial will improve the safety index for the next missions. The composite fiber graphite, shown by blast overpressure testing to be stronger than bulk graphite, also leads to an improved safety index, as well as to a modest weight reduction.

These improved heat source materials and components entered the production phase for the NASA Galileo mission (Jupiter Orbiter/Probe) scheduled for launch in early 1982. Unfortunately, selenide-based thermoelectric elements, expected to provide approximately 10 percent conversion efficiency for the Galileo mission, failed to show adequate stability and power output in prototype ground test generators. As a consequence, the decision was made to reinstate use of silicon-germanium converters, already performing reliably on the DoD Les 8/9 and NASA Voyager spacecraft.

The spacecraft designer continually strives to support a maximum of scientific experiments or informational/navigational systems at a minimum payload weight. The electric power-producing generator is vital to either of these functions and it too must be optimized at the maximum power output per unit of weight. The General Purpose Heat Source (GPHS) was developed to provide a versatile, modular plutonium-238 fueled unit suitable for numerous space applications, yet showing improved specific power (watts per pound) and safety index. The improved iridium-tungsten alloy and the composite fibrous graphites already mentioned are applied in the construction of the fuel module components. Each module, fueled with four 62.5-thermal-watt plutonium-238 fuel pellets, is designed to survive potential accidental reentries and to impact the Earth with minimal consequences.

The GPHS modules and the silicon-germanium thermoelectric converter couples are specified for the NASA International Solar Polar Mission. With continuing design refinements and analytical studies, and by planned improvements to the power system, the performance level of the generators should attain a specific power of approximately 5.5 watts per kilogram. The spacecraft requirement for 286 watts electric at beginning of life, and 275 watts after two years of service, is expected to be met by

a radioisotope thermoelectric generator (RTG) comprising 18 heat source modules, weighing in at 52 kilograms. This mission represents a new challenge in coordination—to ensure compatibility of components with both the NASA and European Space Agency (ESA) spacecraft as well as to achieve appropriate trajectories in opposite directions through the plane of the ecliptic and over/under the poles of the Sun.

Dynamic Isotope Power Systems

In FY 1978, two competitive radioisotope-fueled dynamic power systems were compared. These systems were the Brayton Isotope Power System and the Organic Rankine Cycle System. Both were designed toward an output power of 1.3 electrical kilowatts. Ground demonstration tests were conducted on systems representing the current state-of-the-art in materials selection, component design, and operational controls. Upon critical evaluation, the Organic Rankine Cycle unit was selected for further development and verification of performance, reliability, and longevity.

The Dynamic Isotope Power System was designed and tested in anticipation of missions requiring 1–2 kilowatts of power. Expected efficiencies in the 18–25 percent range would encourage consideration of the nuclear option for power output in this range, since compactness, longevity, and high performance were attributes of these dynamic systems also. Studies directed toward potential DoD applications were conducted in depth, with particular emphasis upon the Nuclear Integrated Multi-Mission Spacecraft.

The Dynamic Isotope Power System originally was planned for operational testing in the DoD space test program, to be launched in late 1982 or early 1983. But during the ground demonstration activity in 1978, the DoD elected to defer the space test program and to encourage instead a continued technology verification program which would improve efficiency of the conversion system and enhance the reliability and performance level of selected components. This program is expected to continue through FY 1980, and will include a 5000-hour endurance test to validate the engineering and design improvements. Upon completion of this test, further dynamic system activity is contingent upon the availability of appropriate mission models, DoD user agency schedules, and reimbursable funding.

Space Reactor Technology

On the basis of prior studies conducted by the Advanced Space Power Working Group, a joint

DoD/DOE committee to examine potential mission requirements for a space reactor in the late 1980s, a technology development program was initiated in FY 1979. The objective is to establish the technology base for a high-temperature, compact space nuclear electric reactor system, producing power in the 10–100 kilowatt range. The five-year program is to complete development of reactor component technology that will support a future system demonstration to be scheduled and funded by the user agency.

Among the applications envisioned for this reactor system are a power supply for spacebased radar operating with satellite power stations, electronic mail systems, advanced television coverage, holographic teleconferencing facilities, and other systems for potential civilian and military assignments.

During FY 1979, a comprehensive report was issued by the Los Alamos Scientific Laboratory, entitled "Selection of Power Plant Elements for Future Reactor Space Electric Power Systems" (LA-7858). In the preliminary design, these power plant elements include a uranium-oxide-fueled reactor providing thermal power to an advanced silicon-germanium thermoelectric converter via molybdenum heat pipes, with sodium as working fluid. The radiator system also employs heat pipes anchored to a titanium structure, to dissipate the excess reactor heat into space.

Advances in Supporting Technology

To meet the continuing escalation of requirements for mission performance, reliability, and safety, corresponding advances must be achieved in fuel preparation, capsule production and welding, process control, quality assurance, and reliability evaluation. To this end, the Savannah River Plutonium Fuel Fabrication Facility is currently producing ceramic fuel spheres for the multi-hundred watt generators for the NASA Galileo mission; to increase the specific power for this and subsequent heat sources, the assay of the plutonium-238 oxide feed material has been increased. The Plutonium Experimental Facility, also at Savannah River, is carrying out preliminary experiments in the fabrication of the 62.5-watt pellets soon to be produced for the International Solar Polar Mission generators. The 62.5-watt fuel form, its fabrication process, design refinements, and encapsulation technology were originated by the Los Alamos Scientific Laboratory.

Operational and reentry analyses performed by the Battelle Columbus Laboratories assisted in the development of the GPHS module. Associated test-

ing and evaluation activities were performed by the Air Force Weapons Laboratory, the Naval Nuclear Weapons Center, and the Applied Physics Laboratory of The Johns Hopkins University. The composite fibrous graphites were tested for blast overpressure resistance by the Los Alamos Laboratory with the Teledyne Energy Systems staff also fulfilling a significant role in the assessment of improved graphites.

Reliability engineering requirements have been reviewed by the Sandia Laboratories and DOE, and an updated program requirements document was issued. The intent of the increasingly rigorous reliability effort is to outline to contractors and bidders the basic practices which must be pursued to provide continued positive assurance that reliability requirements for space missions will be met.

Status of Prior Missions

Data transmittals from the Pioneer 10 and 11 and Viking 1 and 2 telemetry systems indicate that the radioisotope generators are performing essentially as anticipated at this point in their life cycle. The multi-hundred watt generators on board the NASA Voyager 1 and 2 spacecraft provide the power for the scientific experiments, as well as the data and photographic transmittals of the fascinating views of Jupiter and its moons received during earlier months in 1979. Similar favorable status has been reported for the communications satellite systems performing on the Les 8/9 missions for DoD. In summary, a reliable performance data base is well established, presaging equivalent or superior performance for nuclear-powered spacecraft in the future.

Satellite Power System

The concept of a Satellite Power System (SPS) in geostationary orbit, employing massive collectors to capture solar energy, concentrating it, and beaming it to Earth antennas, has been studied since 1968. In 1977, the DOE and NASA started a 3-year assessment of the SPS concept to begin learning about the technical and economic feasibility, the environmental and societal impacts, and the merits of SPS relative to other future energy options. A national team is making excellent progress toward the study's planned completion date in 1980.

NASA has specified a reference SPS around which the assessment is being made. Also DOE has identified emerging technological developments which might be incorporated to SPS' advantage. Experimental studies to determine the effects of micro-

waves (the means for transmitting the energy from the satellite to Earth) on biological systems—bees, rodents, birds, and ultimately on man—have been started. The effects of the deployment and operation of the SPS on the environment, on the atmosphere, and on space workers are being assessed. Experiments measuring the impact of the SPS microwave beam on telecommunications and electronic systems are underway. Some 40 generic systems that can be impacted are identified, including radars, microwave links, computers, and satellites. Mitigating strategies for most of these systems are being studied.

In the societal assessment, eligible rectenna sites are being found, tentative materials requirements are being established, the U.S. institutional issues are being studied, the international implications are being assessed, and the need for public involvement is being recognized and fostered. Preliminary assessments of the costs, performance, health and safety impacts, and land requirements for SPS and other future energy options are being made.

Nuclear Waste Disposal

In support of the NASA-DOE study of the potential for nuclear waste disposal in space, a baseline operational scenario was selected during 1978, using the Space Shuttle to place waste into a long-term stable solar orbit between Earth and Venus. In 1979, alternative space concept definitions were further evaluated to enable an early decision regarding future studies.

Remote Sensing of Earth

Several DOE programs benefit from the data provided by NASA-developed satellites that carry instruments sensing the Earth's surface and atmosphere. Examples of present activities include enhancement of exploration technology for uranium, natural gas, and oil; geological characterization of potential nuclear waste disposal sites; and survey of other potential energy facility sites for environmental and seismic suitability. Increased use of data from existing, planned, and future satellite platforms in these and other energy-related activities is anticipated.

Nuclear Test Detection

Development of satellite-borne nuclear surveillance began in the early 1960s and led to the Vela Hotel program. Because of its specialized knowledge of nuclear explosion characteristics and capability to detect and measure output radiations, the

Atomic Energy Commission, one forerunner of the DOE, was tasked to design and develop the detector instrumentation for the proposed satellites, while DoD managed program activities and schedules. The Vela satellites were launched into Earth orbits of about 112,000 kilometers—far enough out so that one satellite could view nearly half the Earth's surface and most of outer space. Six pairs of Vela satellites were placed into orbit between 1963 and 1970. Successive satellites carried improved instrumentation for nuclear-explosion surveillance.

The nuclear surveillance mission of the Vela satellite program is now incorporated into other multi-mission DOD spacecraft and DOE retains responsibility for design, fabrication, test, calibration, and launch and operational support of the instrumentation subsystems for nuclear test detection. In support of this responsibility, DOE conducts a vigorous research and development program to meet changing detection requirements as well as to develop a detailed understanding of the radiation environment of space.



Introduction

The Department of the Interior is responsible for administering the nation's public lands and for maintaining a balance between the use and conservation of natural resources on these lands. Effective resource management and research require accurate and timely data, whether collected on the ground, from high- or low-altitude aircraft, or from satellites. In some investigations data from various sensors such as multispectral scanners, cameras, and radars are useful. To collect data, the department relies on aircraft for acquiring aerial photographs, carrying experimental airborne instruments, and executing programs such as selection of utility corridors, cadastral surveys, and resource inventories.

The need for surveying and repetitive monitoring of vast and often inaccessible areas has also created a growing interest in data obtained from Earth-orbiting satellites, primarily from the experimental Landsat system because of its synoptic, repetitive, and uniform coverage. Digital Landsat data have made possible the extraction of information by computerized techniques. Because of the flexibility that digital data offer in collecting and managing large volumes of information, resource managers in seven bureaus of the department are incorporating varying amounts of this new technology into their routine activities, such as estimating ground water use and determining the movement of sea ice.

Earth Resources Observation Systems Program

The Earth Resources Observation Systems (EROS) Program is administered for the Interior Department by the U.S. Geological Survey (USGS). The purpose of the EROS program is to develop, demonstrate, and encourage applications of remotely sensed data acquired from aircraft and spacecraft.

The key facility of the EROS program is the EROS Data Center (EDC) in Sioux Falls, South Dakota, which is the principal archive for remotely

sensed data collected by USGS and National Aeronautics and Space Administration (NASA) aircraft, and by Landsat, Skylab, Apollo, and Gemini spacecraft. EDC now serves as the national distributor of Landsat products to all agencies of the Federal government and the public. Sales for fiscal year (FY) 1979 amounted to about \$3.4 million, about 65 percent of which was Landsat data.

Improvements in Landsat Data Processing and Handling

Digital image processing systems installed in 1978 at NASA's Goddard Space Flight Center (GSFC) and at EDC were placed in production on February 1, 1979, and have offered major improvements in the quality of Landsat data available to the user. In addition, a domestic satellite communications link (Domsat) became operational in May 1979, allowing transfer of current Landsat data from receiving stations in Alaska and California to GSFC, and from GSFC to EDC via a telemetry link instead of the postal service.

The EDC data base was improved by indexing (but not archiving) all Landsat data holdings acquired by reception stations in foreign countries. This is the first international Landsat data base in existence and establishes in the United States a single worldwide point of contact for Landsat data. Current participants in this data base integration include the European Space Agency (with processing centers in Italy and Sweden), Brazil, and Canada. Data listings from Japan, Australia, India, Argentina, and other locations will be added in the near future.

Continued improvements are planned for the next year, including modification of the digital image processing system at EDC to accept unresampled Landsat data and to perform geometric corrections.

Training Programs

Training in the form of workshops and courses at EDC is provided at cost for resource specialists and

land managers interested in remote sensing technology. Approximately 25 workshops are offered each year to about 500 scientists, both domestic and foreign. After 5 years of conducting 120 training sessions involving more than 2500 participants, the Center has noted a shift in demand away from general, introductory remote sensing courses toward courses that emphasize specific scientific disciplines or resource information and management techniques. The Center also cooperates with qualified universities in presenting workshops on techniques and on applications to specific disciplines. These workshops are offered to practicing professionals, through university extension programs.

Applications and Research

In addition to data distribution and training, EROS activities include technical assistance and research in the applications of remotely sensed data to Earth resources investigations. Computer-assisted image analysis techniques are developed, demonstrated, and documented in the Data Analysis Laboratory at EDC in response to the needs of user agencies. Cooperative demonstrations and research projects develop and test techniques feasible for operational use. Following are some examples of promising new cooperative projects with potential for routine use in the department.

Land Use and Land Cover Maps. In late March 1979, a nuclear accident occurred at the Three Mile Island power plant near Harrisburg, Pennsylvania. The location of this power plant on the Susquehanna River, 16 kilometers from the state capital, raises the question of where such plants should be located in terms of the hazards to nearby urban, industrial, and agricultural areas. To aid in evaluating and recommending solutions for control of such hazards, a special land use and land cover map, keyed to political units and census statistical areas, was digitized from high-altitude aircraft data by a computer-driven plotter. The computer-drawn map was then placed over a standard USGS topographic quadrangle at the same scale of 1:100,000. Nineteen detailed land use categories were identified by colors and shading patterns. Rings at 8-kilometer intervals and place names were added for evaluation of potential hazards and for site planning. The remotely sensed digital data used in constructing this land use and land cover map were obtained from a data base compiled in 1978 as a cooperative effort between the Pennsylvania Department of Environmental Resources and the Geological Survey.

Archeology. The National Park Service (NPS), working in close cooperation with EROS and several other Federal agencies and major universities,

is using remotely sensed data, primarily from aircraft but supplemented by Landsat, to identify and evaluate historic and prehistoric cultural resources in the national parks. In the San Juan Basin Regional Uranium Study, sponsored by the Bureau of Indian Affairs, remotely sensed data from aircraft and Landsat are being used to assess the effects of uranium exploration and development upon the parks and archeological sites and upon the culture of the Navajo Indians living in the region.

Ground Water Use. The USGS has the responsibility to estimate the quantity of water our nation uses annually for industrial, domestic, and agricultural purposes. An important part of this responsibility is to determine the ground-water pumpage for irrigation of crops. Techniques have been developed to utilize Landsat data to determine the areas of crops irrigated and to use these data in conjunction with selective sampling of pumpage at well heads to estimate the total quantity of water pumped. Results from demonstration projects in the Suwanee River Water Management District, Florida, and an eight-county site in the tri-State area of Colorado, Nebraska, and Kansas, indicate that the inclusion of Landsat data improves the reliability of the water-use estimates, shortens the time for analysis, and costs less than estimates based upon conventional methods alone.

Monitoring Snowmelt Runoff. The USGS participated with NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Salt River Project, Arizona, in developing methods to monitor rapidly changing snow conditions and to predict snowmelt runoff quantities using satellite imagery and radio-transmitted hydrologic data relayed by satellite to ground receiving stations. These data were made available to officials of the Salt River Project and were used for near real-time management decisions involving reservoir operation. Use of the satellite relayed data and satellite imagery has improved the accuracy of short-term runoff prediction and the efficiency of reservoir operations.

Sea Ice. From data obtained during the Nimbus 5 experiment, the USGS produced a remarkable time-lapse movie covering several years' collection of satellite microwave images of the Arctic Polar Region. The movie dramatically displays the growth, distribution, and breakup of sea ice. This clear demonstration of the dynamic nature of the Beaufort Sea should be of value to navigators of ships, geologists interested in offshore petroleum exploration, and planners of logistic operations.

Monitoring the Environment

Land Inventories

EDC and the U.S. Fish and Wildlife Service are cooperating in a project to demonstrate the use of Landsat data in an inventory of the vegetation and land cover of wildlife habitats.

EDC is also cooperating with the Bureau of Land Management (BLM) in a demonstration project to evaluate the application of remote sensing technology to mapping and inventorying vegetation on BLM lands. Multispectral scanner digital data acquired by Landsat and digital terrain data were used to classify approximately 100 square kilometers in northwestern Arizona into nine land cover types using the interactive image analysis system at EDC. Large-scale aerial photographs were used to determine the vegetation type of selected picture elements. Results showed that integration of digital Landsat data and terrain data can significantly improve the accuracy of vegetation classification.

Scientists from the U.S. Forest Service Northern Forest Fire Laboratory are also attempting to use digital Landsat data and terrain data to identify forest vegetation classes that can be used to map forest fire fuels over large areas. The data will then be used for management actions to reduce fire hazards.

The NPS completed a project for the Everglades National Park with the assistance of EDC. A hydrologic model for Shark Slough was developed that required information on water depth, volume, and temporal changes in the water margins of the slough. By using data from Landsat and 76 measurement stations, water depth and volume were determined. One of the more interesting findings was that a 10-fold decrease in the water volume halved the slough margin.

The NPS also used enhanced Landsat images in their New Area Studies Program. The images were photographically enlarged and manually interpreted to provide general vegetation, land use, landform, drainage, and other land cover information. A significant aspect of these projects was that they were all completed in two or three weeks at a cost of only a few thousand dollars.

Environmental Impact of Fuels Exploration and Development

The Bureau of Mines, Office of Surface Mining, and EROS provided support for the development of minicomputer digital equipment and analytical techniques for monitoring surface mining operations using Landsat data. Low-cost systems were de-

veloped and installed at Stanford University and at the Technology Application Center of the University of New Mexico. Field investigations using these systems were conducted in New Mexico, Oklahoma, and South Carolina.

The Conservation Division of the USGS, working with the EROS program, has been closely monitoring the blowout from Mexico's Pemex oil well Ixtoc 1 in the Gulf of Mexico. The monitoring has been done in collaboration with the U.S. Coast Guard and NASA. Landsat data were used to detect and delineate oil floating westward from the well in the Bay of Campeche to the coastline between Vera Cruz and Tampico and then northward into Texas waters between Brownsville and Galveston. A mosaic of four Landsat images, prepared by the Survey, was used as a guide for July flights of the Coast Guard C-130 Airborne Oil Surveillance System aircraft to oil-contaminated areas and to aid NOAA's scientific support coordinator and the Coast Guard's on-scene coordinator in predicting when oil from the runaway well would reach U.S. waters.

Alaska

Near-real-time satellite data are being used in the Quick-Look Project to produce sea-surface temperature maps for the fishing industry, analyses of sea-ice conditions for personnel working offshore on the ice in the Beaufort Sea, and images showing the location of fires. The project uses data from the Defense Meteorological Satellite, NOAA satellites, and Landsat. Information provided by the images led to the evacuation of a drill rig on ice in the Beaufort Sea and prediction of an outburst from a glacier-dammed lake west of Anchorage.

BLM and several other agencies have been using a Meteor Burst Communications System (transmission of short messages over ionized trails left by meteors entering the upper atmosphere of the Earth) in Alaska over the past few years. BLM will be testing meteor burst communications in conjunction with aircraft on-board navigation systems to automatically relay aircraft positions from remote areas independently of aircraft elevation or terrain. This system will greatly enhance the safety and dispatch capability of flights in inaccessible areas.

Data Acquisition through Satellite Relay

The USGS continued to expand the number of platforms transmitting environmental data through the Geostationary Operational Environmental Satellite (Goes). An increase to 150 platforms was

in part necessary because the use of Landsat to relay data was discontinued. The USGS has also contracted with Comsat General Corp. to test a pilot real-time information service involving 75 hydrologic data-collection platforms. This pilot test service will begin operation in late 1980.

The BLM is concluding a project with the U.S. Forest Service to provide standard Remote Automatic Weather Stations for Fire Management by relaying data through the Goes satellite.

The Water and Power Resources Service began construction of its Hydromet and Meteorological Surface Observation Network (Mesonet) system and contracted with Colorado State University (CSU) to analyze cloud systems by the use of satellite data. The Hydromet system will collect hydrologic and meteorologic data from sensors on 70 data collection platforms and then transmit these data via the Goes satellite to a receiving antenna in Boise, Idaho. Mesonet is a solar-powered network of 150 portable meteorological stations that use a Goes satellite-computer link to enable scientists to monitor weather developments in great detail even though they occur over large areas many miles away. The weather data will be relayed to a ground receiving station at Wallops Island, Virginia. The CSU study will support two Bureau research projects: the High Plains Cooperative Project in growing-season rainfall management, and the Sierra Cooperative Pilot Project in winter snowfall enhancement.

Geology

Mineral Exploration

Landsat imagery and aerial photographs are used by the department as a tool for mineral exploration and to improve the quality and speed of mineral resources mapping.

In the southern Powder River Basin, Wyoming, many of the uranium producing areas are obscured by vegetation that covers 50-75 percent of the ground. A Landsat computer-enhancement technique was developed to map the regional vegetation variations that reflect subtle changes in lithology, chiefly the proportions of sandstone and mudstone. By this technique it was discovered that uranium deposits are associated with a particular lithology that has an intermediate sandstone/mudstone ratio. Lineament analyses were used to develop a model for the influx of uranium-bearing groundwater into the basin and subsequent deposition of uranium.

In a jointly funded United States-Mexico experimental project in northern Sonora, Mexico, analysis of lineaments and limonitic occurrences seen in

Landsat images was used to identify promising areas for more detailed geologic mapping and geochemical surveys. Strike-frequency analysis of mapped lineaments indicated the presence of two statistically significant trends, northeast and northwest. At least four northeast-trending lineament zones were defined and are interpreted to be structural zones that were the primary regional control of mineralization in the porphyry copper deposits of northern Sonora. Although northwest-trending structures also appear to have influenced the localization of ore deposits, these are pervasive structures which are not useful as regional prospecting guides. In contrast, the northeast-trending lineament zones are localized and systematic and are characterized by concentrations of limonitic hydrothermally altered rocks, occurrences of known copper deposits, and anomalously high lead content in stream sediment. These data, along with other geochemical and geophysical data, have resulted in the identification of several areas of exceptional economic potential, and this approach has become an integral part of the mineral appraisal studies being conducted by the department.

Field investigations in the Williamsport Valley, Pennsylvania, to identify lineaments shown on Landsat return beam vidicon images revealed the presence of six discrete fault zones whose strike is subparallel to the trend of the Appalachian folds. These zones range from 0.5 to 1.75 kilometers in width and from at least 10 kilometers to more than 50 kilometers in length. Many thrust faults of only a few centimeters displacement are present within each zone and occur at low angles in the beds of "staircase-type" folds. The extreme degree of faulting and staircase-type structures may indicate fracture porosity traps for gas and oil at depth.

Other programs using remote sensing techniques include nuclear waste disposal, mineral resource appraisal, geothermal studies, and volcanic hazards.

Lunar and Planetary Studies

Studies of the moon and of data from the two successful Viking missions to Mars are continuing, but the flybys of Voyagers 1 and 2 past Jupiter and the mapping of the Venusian surface using the Pioneer radar altimeter have provided the most significant findings. Preliminary studies of the four large Galilean satellites of Jupiter indicate a great diversity in surface composition and morphology. Dark areas on Io may be flows of molten sulfur, and volcanic eruptions were actually observed. Europa has a system of long, linear structures. Ganymede is probably composed of an ice-rock crust over a dominantly water mantle. Callisto possessed an enor-

mous multi-ring impact basin. On Venus, the Pioneer satellite is providing data for a radar map of 70 percent of the surface of the planet. Early results indicate the presence of active volcanoes and some high mountains.

Cartography

Studies to develop techniques for applying satellite data to cartography concentrated on the use of Landsat 3 data. Computer programs were prepared that use the Hotine Oblique Mercator (HOM) and Space Oblique Mercator (SOM) projections for Landsat data. These programs compute geographic latitude and longitude coordinates from the HOM or SOM coordinates or vice versa. Additional investigations produced the specifications of map projections for other satellite applications. Geometric considerations for a mapping satellite system were studied.

Landsat Image Maps

Experimental image maps of the coal-rich areas of Montana and Wyoming were prepared from Landsat data. A unique map combining Landsat MSS imagery with line-map data for the Wenatchee, Washington, 1°×2° quadrangle was printed at a 1:250,000 scale. This map meets national map accuracy standards for the accuracy of horizontal positions at that scale and was selected as a prototype for use in areas of Latin America where data for larger scale maps are not available.

High-Altitude Aerial Photography

A program of high-altitude aerial photography mapping administered by the U.S. Geological Survey for several government agencies has as its goal complete coverage of the conterminous United States. A solicitation for bids for photographs of about one-fifth of the country was issued near the end of 1979. The photographs will be acquired simultaneously with two different focal-length cameras and will be on both color-infrared and black-and-white film. The scales of the negatives will be approximately 1:60,000 and 1:80,000, respectively.

International Activities

Under the U.S. Foreign Assistance Act, USGS participates with the Agency for International Development (AID) in a technical assistance program to aid developing countries in Earth-science and engineering applications. These countries frequently request assistance in remote sensing as the most feasible way of solving some of their environmental and resource problems.

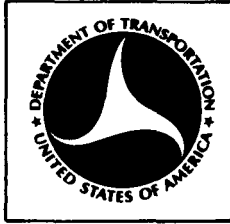
Four-week international remote sensing workshops are given at EDC twice a year as part of this program. In FY 1979, 37 scientists from 18 foreign countries attended the workshops. EDC also coordinated a training course in remote sensing under the auspices of the Circum-Pacific Council in Honolulu, Hawaii, for some 60 scientists from Pacific and Far East countries. A remote-sensing training workshop was held in the People's Republic of China during June 1979 at the Scientific Research Institute for Petroleum Exploration and Development, Ministry of Petroleum.

Advanced training courses in geologic interpretation, land use planning and environmental applications, and digital image processing were conducted for foreign participants by the USGS Center for Astrogeology in Flagstaff, Arizona, during the year. A new course for foreign Earth scientists, covering the basic principles of digital image processing, is to be held at the USGS National Center in FY 1980.

Another international activity of USGS is cooperation in scientific research and the exchange of information. Landsat imagery is an important component of several ongoing tasks under a long-term USGS cooperative agreement with Saudi Arabia. Digitally enhanced imagery is used extensively in geologic interpretation and as a base for geologic and geographic maps and mosaics at scales ranging from 1:100,000 to 1:2,000,000.

In addition, USGS scientists participate in many assistance programs and consultations in the developing countries. A current AID-sponsored project in Tunisia, for example, is developing skills in production and interpretation of satellite imagery for investigations in geology, hydrology, pedology, erosion, desertification, and pollution.

A remote sensing project, led by USGS, is part of the International Geological Correlation Program, which is jointly sponsored by United Nations Educational, Scientific, and Cultural Organization and the International Union of Geological Sciences.



Introduction

The Department of Transportation, through its aviation component, the Federal Aviation Administration (FAA), engages in extensive aeronautical research, development, test, and evaluation activities. These support the basic responsibilities of FAA to regulate air safety, ensure the safe and efficient utilization of the nation's airspace by both civil and military users, and foster the development of civil aeronautics and air commerce.

Aviation Safety

FAA's research, development, and engineering programs in aviation safety are designed to demonstrate the technical, operational, and economic feasibility of improving aircraft performance and raising the performance standards for pilots and other airmen. During 1979, FAA continued to work in concert with NASA and the Department of Defense to improve the safety of both fixed-wing and rotor-type aircraft; major emphasis was placed on post-crash fires, airframe crashworthiness, turbine-engine ingestion, and icing. New means of preventing or deterring acts of terrorism or other violence aboard aircraft and at airports were vigorously pursued. In the area of aviation medicine, FAA sought to identify and eliminate biomedical factors in aviation accidents and to improve the performance, health, and safety of pilots, ground personnel, and passengers. The knowledge acquired in all of these programs enables FAA to improve contemporary and future aircraft and ensure the issuance of appropriate new standards, certification criteria, and regulations.

Fire Safety

FAA continued to work toward improving the chances of aircraft occupants surviving an impact-survivable crash involving a fuel-fed fire. Large-scale fire tests were conducted that simulate what actually happens inside an aircraft fuselage during

various types and stages of fires. These tests, utilizing a C-133 fuselage to simulate a full-scale, wide-body jet, were conducted at the National Aviation Facilities Experimental Center, in Atlantic City, New Jersey. The tests were designed to measure carbon monoxide levels, smoke intensities, and heat released inside the fuselage from a fire fed by an exterior burning fuel without any contribution from interior cabin materials. Similar tests will include burning interior materials to establish their contribution.

Fuel-fed fires can kill all the survivors of an impact-survivable aircraft accident. Fuel spewed from ruptured tanks forms fine mist-like particles that readily ignite and then create an all-consuming fire ball. In attacking this problem, FAA directed its efforts toward the development of a fuel additive that would minimize the formation of the mist-like fuel particles and thereby reduce the possibilities of a fire ball being created. Numerous small and mid-sized tests simulating spillage from a ruptured fuel tank in the presence of an ignition source were conducted during 1979. Varying amounts of additive and levels of ignition intensity were used in order to establish parameters for the large-scale tests, which were conducted during the latter part of the year.

Such considerations as the stability of the modified fuel in storage and handling and during transport within the various aircraft systems were also investigated. A simulation test was conducted to determine how well the modified fuel could pass through an aircraft system; the test results were promising. The compatibility of the modified fuel with engine components is being determined in a joint effort between FAA and NASA. All aspects of this investigation to date have been encouraging.

FAA was also engaged during the year in improving and expanding a mathematical model developed by the FAA to simulate aircraft cabin fire. The model is being validated by comparing its results with those obtained from on-going FAA-NASA cabin-fire tests. The validated model will be used to evaluate concepts to improve cabin-fire safety through compartmentation, and the agency

plans to sponsor a workshop to encourage and facilitate use of the completed model by industry. In concert with this effort, improved evacuation techniques are being developed for incorporation into existing and future aircraft designs.

Finally, FAA made good progress during the year toward a "combined hazard index" identifying cabin interior materials that will not contribute to the hazards of a fire. This index takes laboratory-scale data generated from burning small samples of material and, by using a mathematical model, identifies the flammability, smoke, and toxic gas emission characteristics of the materials.

Aviation Security

Efforts to deter acts of terrorism and sabotage aboard aircraft and at airports concentrated on improving techniques for detecting explosives in checked baggage and other items. A transportable baggage bomb detector was constructed and readied for airport testing. Enforcement officials were provided with the vapor characteristics of a broad range of explosives for use in evaluating screening units in an operational airport environment.

Small animals continued to be tested for their potential in detecting the minute quantities of vapors emanating from explosives. The behavior of these animals was assessed under actual airport operating conditions. The animals' performance is being compared with that of electronic vapor detectors. Additionally, the characteristics of a screening system employing dual-energy x-ray techniques (including computer-aided tomography) were developed and made available to users.

Airport Pavement

Airport pavements must be evaluated periodically for their strength characteristics and load-carrying capabilities. Conventional testing methods call for cutting test pits measuring 1.2 square meters into the airport pavement, conducting plate-bearing tests, and sampling materials. This method is both costly and time-consuming and requires shutting down the runway or taxiway. An alternative, non-destructive testing method has been developed, however, which eliminates digging pits and minimizes the time runways are shut down. Vibration is applied to the pavement, its deflection is measured, and its strength and load-carrying capability is calculated by a computer. Seminars explaining this technique were held at four airports, and the details of this method were provided to airport operators.

In another development, FAA continued to determine the optimum groove configuration to im-

prove runway traction during wet weather. Grooving configurations, installed while bituminous surfaces were still plastic, were tested during 1979. These tests have now been completed.

Aviation Medicine

As aviation technology expands and grows in complexity, advances in air safety depend increasingly upon a broader understanding of human capabilities and limitations and of the relationship between the operator and the machine in the aeronautical environment. Assessing and improving the performance of the human operator, whether in the cockpit or in the control tower, therefore, is a primary area of exploration for the FAA medical research program.

FAA recently applied simulation theory to all phases of air traffic controller selection, assessment, job structuring, and training. The objective of the program was to develop a performance-based system to evaluate a controller from initial selection as a candidate through his or her progression as a trainee to full proficiency. New selection tests were developed and administered experimentally to students entering training and to personnel on the job at operational facilities. These tests produced a higher correlation with air traffic controller success than any other tests used in previous evaluation studies. They promise to be significantly better for screening applicants.

New skill tests were also developed and used, along with instructor evaluations, to measure how well students applied knowledge and skills during the first months of training. Data collected from these measurements were used to assess and improve the quality of training and to evaluate candidates at the end of their course. The net result has been a continuing internal self-improvement system that improves training and selection and promises to provide quality controllers at lower cost.

Other Safety Developments

In other safety developments, FAA

- Continued to investigate the new technologies employed in the new generation of energy-efficient transport aircraft that use active control systems and digital avionics. Fixed-wing aircraft systems were validated in 1979 using simulation methods.
- Developed helicopter crash scenarios to investigate the feasibility of using general aviation crashworthiness models for helicopters.
- Began a joint program with the U.S. Army to establish parameters upon which icing criteria for helicopter certification could be based.

- Continued research on general-aviation pilot training and certification, general-aviation aircraft cockpit standardization, and crash-impact design standards for general-aviation aircraft. Factors relating to the recognition of stall and spin were identified, and the next phase of pilot judgment training was begun. Experimental training syllabi were developed for both flight instructors and student pilots; the goal is to produce better and safer civil pilots by exposing them to a structured judgment training program.

Air Traffic Control and Air Navigation

Discrete Address Beacon System

FAA currently uses the existing Air Traffic Control Radar Beacon System (ATCRBS) as the primary means of tracking and surveillance in air traffic control automation operations. In this system, when an airborne transponder is triggered by ground interrogators, it responds by transmitting the aircraft's identity and altitude. ATCRBS, however, has one serious shortcoming—a limited ability to separate transponder replies coming from aircraft in the same immediate vicinity. Air Traffic Control Radar Beacon transponders respond indiscriminately to all ground station interrogations; this causes overlapping and garbling of transponder replies and seriously limits the system's ability to meet the demands of the automated air traffic control system.

To overcome this difficulty, FAA has developed an improved ATCRBS, the Discrete Address Beacon System (DABS), which assigns a unique address code to each aircraft. The airborne DABS transponder will respond only if an interrogation contains this code. This ability to interrogate discretely makes the Discrete Address Beacon System a natural digital data link between the ground-based air traffic control system and aircraft. DABS also has the capability to provide an automatic ground-derived traffic advisory and separation assurance not available with the ATCRBS. Transition from the Air Traffic Control Radar Beacon System to the Discrete Address Beacon System will require between 10 to 15 years to complete.

FAA has ordered three engineering models of the discrete system. Two models were delivered in 1978; the third, delivered in April 1979, possesses the ground-based separation assurance capability. The three models have been installed in the vicinity of FAA's National Aviation Facilities Experimental Center, where they are currently undergoing test and evaluation.

Microwave Landing System

Activities with a Microwave Landing System (MLS) proceeded as scheduled. FAA has developed three versions of a Microwave Landing System: a basic wide aperture, a basic narrow aperture, and a small community system. The basic narrow aperture and small community systems have been tested and evaluated. Testing of a basic wide system, intended for large airports, was begun during 1979 at NASA's Wallops Flight Center. Meanwhile, other efforts were directed toward (1) the development and international approval of International Civil Aviation Organization (ICAO) Standards and Recommended Practices, (2) drafting implementation and transition plans, and (3) establishing final production specifications for basic narrow and small community systems.

The Systems Test and Evaluation Program (STEP) currently underway provides user communities with "hands on" experience with an MLS and permits the gathering of "live" operational data for use in developing handbooks, siting standards, and flight inspection procedures. During the first phase of the program, small community systems will be installed at Philadelphia International Airport, Washington National Airport, and Bader Field (Atlantic City) early in 1980. A basic narrow system has already been installed at Washington National Airport; tests and calibration flights began in late 1979. Planning for the second phase of the program includes the procurement of 16 microwave systems—eight small community and eight basic narrow.

Wind Shear

FAA's wind shear program is designed to detect and forecast hazardous wind-shear conditions and assist pilots in coping with them. The major portion of this program is scheduled to be completed in 1980.

Flight profile simulations, conducted in cooperation with NASA, have been completed and have formed the basis for an Advance Notice of Proposed Rulemaking, issued by FAA in May 1979. The advance notice proposes to require that passenger-carrying aircraft be equipped with devices that will display wind-shear information to the pilot. Many airlines have already incorporated the results of these simulation studies in their standard training procedures.

As part of the effort to mitigate the effects of low-level wind shear on aircraft terminal operations, FAA developed and tested the Low-Level Wind Shear Alert System (LLWSAS). The system consists of remoted anemometers mounted between

6 and 12 meters above the ground in the approach and departure corridors of a number of the nation's busiest airports. Wind data from the remoted anemometers are reported to a central airport location (normally the air traffic control towers) for processing and comparison with data sensed by the centerfield anemometer. When a vector difference of at least 28 kilometers per hour is detected, an alert is displayed in the air traffic control tower cab. Installation and commissioning of these systems began in September 1978. Development of forecasting techniques for predicting low-level wind shear conditions is continuing.

Electronic Tabular Display System

Although a significant degree of automation has been introduced in the 20 air route traffic control centers located in the contiguous 48 states, many routine functions are still being performed manually by air traffic controllers—especially the updating and posting of flight progress strips in controller consoles and the manual entry of new flight data into the en route computers.

In January 1979, FAA awarded a contract to develop an engineering model of an Electronic Tabular Display System (ETABS). Its design objective is to provide a more efficient method of displaying and updating flight plan data, thereby eliminating the need for paper flight-progress strips. The potential payoff is significantly improved control-team efficiency and productivity. During 1979, an in-depth evaluation of ETABS was conducted by a team of experienced field personnel to judge its impact on operations and maintenance in field facilities. The evaluation team strongly supported the operational concept and identified factors that will be considered during implementation planning to minimize the impact on field facilities.

Terminal Information Processing System

The Terminal Information Processing System (TIPS) is an air traffic control terminal automation program that has the potential for increasing the productivity of the terminal controller. Through the automated features of the TIPS computer and associated electronic displays, terminal controllers will be provided with an improved system for proc-

essing and distributing flight data and other essential operational information. Today these tasks are performed manually at the terminals; flight data are distributed by means of paper flight progress strips that are cumbersome to handle and require manual updating.

A procurement contract has been awarded for the development of a prototype TIPS system. The prototype will be installed in the terminal test bed at the National Aviation Facilities Experimental Center in 1980 for test and evaluation.

Airport Surface Traffic Control

The goal of this research and development program is to develop automation and surveillance aids for airport surface traffic control to minimize surface traffic delays and provide safer airport operations under all weather conditions. A major element in this development activity is a new radar—Airport Surface Detection Equipment (ASDE-3), which will provide improved aircraft detection during fog and rain. A prototype ASDE-3 was delivered to the National Facilities Experimental Center in August 1979 and is now undergoing test and evaluation.

Vortex Advisory System

The Vortex Advisory System (VAS) is designed to permit better utilization of airport capacity by minimizing the impact of trailing wake vortices on the sequencing and spacing of aircraft in arrival and departure corridors. This system deploys a network of anemometers located in the runway approach zones to measure wind conditions, the major element influencing vortex stability. These data are fed into a processor, where the conditions are analyzed and sent to the air traffic controller, who then establishes aircraft separation parameters. The system is currently being evaluated at Chicago's O'Hare International Airport and is scheduled to be commissioned early in 1980.

On-going and future work includes development of techniques to select improved locations for weather sensors, refinements to the algorithms, assessment of the possibility of decreasing departure spacing, and a manned flight simulation to assess the vortex hazard as it relates to aircraft spacing and altitude of encounter in the approach corridor.

Appendixes

APPENDIX A-1

U.S. Spacecraft Record

Year	Earth orbit		Earth escape		Year	Earth orbit		Earth escape	
	Success	Failure	Success	Failure		Success	Failure	Success	Failure
1957	0	1	0	0	1969	58	1	8	1
1958	5	8	0	4	1970	36	1	3	0
1959	9	9	1	2	1971	45	2	8	1
1960	16	12	1	2	1972	33	2	8	0
1961	35	12	0	2	1973	23	2	3	0
1962	55	12	4	1	1974	27	2	1	0
1963	62	11	0	0	1975	30	4	4	0
1964	69	8	4	0	1976	33	0	1	0
1965	93	7	4	1	1977	27	2	2	0
1966	94	12	7	1	1978	34	2	7	0
1967	78	4	10	0	1979	18	0	0	0
1968	61	15	3	0	Total	941	129	79	15

¹ This Earth escape failure did attain Earth orbit and therefore is included in the Earth orbit success totals.

NOTES: The criterion of success or failure used is the attainment of Earth orbit or Earth escape rather than a judgment of mission success.

This tabulation includes spacecraft from cooperating countries which were launched by U.S. launch vehicles.

"ESCAPE" flights include all that were intended to go to at least an altitude equal to lunar distance from Earth.

APPENDIX A-2

World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

Year	United States	U.S.S.R.	France	Italy	Japan	People's Republic of China	Australia	United Kingdom	European Space Agency
1957		2							
1958	5	1							
1959	10	3							
1960	16	3							
1961	29	6							
1962	52	20							
1963	38	17							
1964	57	30							
1965	63	48	1						
1966	73	44	1						
1967	57	66	2	1			1		
1968	45	74							
1969	40	70							
1970	28	81	2	1	1	1			
1971	30	83	1	2	2	1		1	
1972	30	74		1	1				
1973	23	86							
1974	22	81		2	1				
1975	27	89	3	1	2	3			
1976	26	99			1	2			
1977	24	98			2				
1978	32	88			3	1			
1979	16	87			2				1
Total	743	1250	10	8	15	8	1	1	1

¹ Includes foreign launchings of U.S. spacecraft.

NOTE: This tabulation enumerates launchings rather than

spacecraft. Some launches did successfully orbit multiple spacecraft.

Successful U.S. Launches—1979

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period Inclination to equator (degrees)	Remarks
Jan. 30 Scatha (STP P78-2) 7A Delta	Objective: To place satellite into a highly elliptical orbit of sufficient accuracy to allow the spacecraft to achieve its final elliptical orbit. Satellite carried 12 experiments to identify and measure sources of electrical charge buildup on the spacecraft. Spacecraft: Cylindrical shape, 1.7 m in diameter and 1.8 m high. Three 3-m booms, one 2 m, and one 7 m, all for deployment of experiments; and a 100-m tip-to-tip electric field antenna. Weight at liftoff: 658.8 kg, and 343 kg after jettison of the apogee motor.	43,214 27,581 1416.2 7.8	U.S. Air Force/NASA spacecraft successfully orbited by NASA launch vehicle. Apogee kick motor fired Feb. 2, placing satellite in correct orbit. Spacecraft returning data. Still in orbit.
Feb. 18 Sage (AEM B) 13A Scout	Objective: To develop a satellite-based remote sensing technique for measuring stratospheric aerosols and ozone, to map vertical extinction profiles of stratospheric aerosols and ozone, to investigate the impact of natural phenomena such as volcanoes and tropical storms, and investigate the sources and sinks of stratospheric ozone and aerosols. Spacecraft: Consists of an instrument module containing the Sage (Stratospheric Aerosol Gas Experiment) sensor and its supporting equipment and a base module. Base module contains all the subsystems necessary to support and control the total satellite. Two solar paddles are mounted on the satellite structure. SAGE sensor is a four spectral channel radiometer which measures the extinction of solar radiation during solar occultation. Weight: 147 kg.	661 548 96.7 54.9	Successfully launched by NASA. First instrument sunrise/sunset events taken Feb. 21. Scientists, using Sage sensor, tracked material deposited in stratosphere by volcano La Soufriere on St. Vincent in the Caribbean, which erupted April 13, 14, and 17, ejecting ash and volcanic gases into the surrounding atmosphere. Ozone and aerosol measurements provided by Sage agree with ground-truth observations. Worldwide distribution of concentration of stratospheric aerosols currently being measured.
Feb. 24 Solwind (STP P78-1) 17A Atlas F	Objective: To gather data on solar wind, sunspots, solar flares, electron build-up in polar regions, and distribution of aerosols and ozone in the atmosphere. Spacecraft: Carries gamma ray spectrometer, particle counter, coronagraph, extreme-UV monitor, extreme-UV spectrometer, solar x-ray spectrometer/spectroheliograph, x-ray monitor, and aerosol monitor. Weight: 1331 kg.	601 576 96.2 97.6	Air Force test program flight for Naval Research Laboratory with Defense Research Projects Agency instrument. Successfully placed in correct orbit. Still in orbit.
Mar. 16 Defense 25A Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	246 170 88.5 96.3	Decayed Sep. 29, 1979.
Mar. 16 Defense 25B Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	625 616 97.0 95.7	Still in orbit.
May 4 Fltsatcom 2 38A Atlas-Centaur	Objective: To launch spacecraft into successful transfer orbit. Spacecraft: Hexagonal shape, composed of payload module and a spacecraft module, 6.7 m high. Weight at liftoff: 1867 kg. Weight after apogee motor fire: 1005 kg.	35,829 35,753 1436 2.6	Second of five planned satellites, successfully launched by NASA for the Navy and the Dept. of Defense. Apogee kick motor fired May 6. Satellite despun May 7. Spacecraft placed in desired synchronous orbit at 23° west longitude. All spacecraft systems turned on and operating nominally. Still in orbit.
May 28 Defense 44A Titan IIIB-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	292 144 88.7 96.4	Decayed Aug. 26, 1979.

Successful U.S. Launches—1979

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period Inclination to equator (degrees)	Remarks
June 2 Ariel 6 (UK 6) 47A Scout	Objective: To place satellite in successful orbit. Space- to investigate cosmic radiation. Spacecraft: Cylindrical body, 130.8 cm high, 69.6 cm in diameter; spin stabilized. Spacecraft power supplied by four solar arrays mounted on deployable booms, with a span of 274 cm. Scientific payload consists of three experiments: cosmic ray detector and two x-ray experiments. Weight: 154 kg.	658 596 97.3 55.8	Sixth satellite in cooperative U.S./ United Kingdom program. Spacecraft launched successfully by NASA. 100th launch of Scout booster. Turned over to the United Kingdom on June 2.
June 6 AMS-4 50A Thor-Burner 2	Objective: To support the Defense Meteorological Satel- lite Program. Spacecraft: 1.2 m wide, 5.9 m long. Has solar arrays. Is 3-axis stabilized. Has visual and IR day and night imagery in resolutions of 3.7 and 22 km, scanning an area 2964 km wide as it moves along its orbit. Also has temperature/moisture sounder, precipitating electron spectrometer, and a density sounder. Transmits both in real time and from tape. Weight: 476 kg.	838 827 101.4 98.7	Still in orbit.
June 10 Defense 53A Titan IIIC	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	36,260 35,800 1448.0 1.9	Still in orbit.
June 27 Noaa 6 57A Atlas F	Objective: To launch spacecraft into a Sun-synchronous orbit of sufficient accuracy to enable spacecraft to ac- complish its operational mission requirements. Spacecraft: Launch configuration, including the apogee boost motor, is 371 cm high and 188 cm in diameter. Solar panels deploy in orbit. Spacecraft structure com- posed of four major elements: reaction control equip- ment support structure (RSS); equipment support module (ESM); instrument mounting platform (IMP); and solar array. The basic structure is identical to the DMSP Block 5D2. Instruments include: Advanced Very High Resolution Radiometer (AVHRR), Data Collection and Location System (DCS), Space Environ- ment Monitor (SEM), Total Energy Detector (TED), Medium Energy Proton Electron Detector (MEPED), High Energy Proton-Alpha Detector (HEPAD); and the Tiros Operational Vertical Sounder (TOVS) com- posed of three instruments: High Resolution Infra Red Sounder (HIRS/2), Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU). Identical instruments carried on Tiros-N launched Oct. 13, 1978. Weight: 723 kg.	826 810 101.3 98.8	Successfully launched by a USAF launch team for NASA and NOAA using a reconditioned booster sup- plied by the Air Force. Noaa 6 was the first NOAA-funded operational spacecraft of the Tiros-N series. Joined Tiros-N as part of a two- satellite system. Apogee kick motor fired June 27. Spacecraft turned over to NOAA for operation July 16.
Aug. 10 Westar 3 72A Delta	Objective: To launch spacecraft into synchronous trans- fer orbit. Satellite to provide transmission of television, voice, and other data throughout the continental United States, Alaska, Hawaii, and Puerto Rico. Spacecraft: Drum-shaped cylinder 156 cm high and 191 cm in diameter, a 153-cm-wide circular directional antenna affixed to top of spacecraft; spin stabilized. Provides 12 color TV channels, 600 two-way telephone calls, or millions of bits of high-speed data for com- mercial users in the U.S. Weight at launch: 576 kg.	35,794 35,780 1436.2 0.0	Third in a series of three satellites, suc- cessfully launched by NASA for Western Union Telegraph Company. Apogee kick motor fired Aug. 11 and satellite placed in stationary equatorial synchronous orbit in a storage mode at 91° west longitude, due south of New Orleans and above the Galapagos Islands.

Successful U.S. Launches—1979

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period Inclination to equator (degrees)	Remarks
Sept. 20 HEAO 3 82A Atlas-Centaur	Objective: To study gamma ray emissions, with high sensitivity and resolution, over energy range of 0.06 MeV to 10 MeV; to measure the isotopic composition of cosmic rays from lithium through iron; to measure the composition of cosmic rays heavier than iron; and to operate the spacecraft and acquire scientific data for at least 6 months. Spacecraft: Similar in design to HEAO 1 and 2. Hexagonal experiment module approximately 3.35 m long and 2.7 m in diameter. Octagonal equipment module 83.8 cm high and 152.4 cm in diameter. Three experiments carried on experiment module: High Spectral Resolution Gamma Ray Spectrometer, Isotopic Composition of Primary Cosmic Ray Experiment, and Heavy Nuclei Experiment. Weight: 2898 kg, including 1314 kg of experiments and a 37.6-kg separation system.	501 486 94.5 43.6	Spacecraft successfully placed in orbit by NASA. Third in a series of three High Energy Astronomical Observatories. One of two primary tape recorders failed, backup recorder switched into operation and is performing satisfactorily. Data being received. Satellite surveyed the galactic plane for gamma rays by the end of the year.
Oct. 1 Defense 86A Titan IIIC	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	41,497 30,443 1445.5 7.5	Still in orbit.
Oct. 30 Magsat (AEM C) 94A Scout	Objective: To obtain accurate, up-to-date, quantitative description of the Earth's magnetic field, develop worldwide vector magnetic field model, compile crustal magnetic anomaly maps, interpret anomalies in conjunction with correlative data of Earth's crust, increase understanding of the origin and nature of the geomagnetic field and its temporal variations. Spacecraft: Consists of instrument module comprised of optical bench, star cameras, attitude transfer system, magnetometer boom and gimbal systems, scalar and vector magnetometers and precision Sun sensor; base module contains the central column, 8 trusses, thermal control louvers, forward and after honeycomb decks, four double-hinged solar panels, electrical power supply system, command and data handling system. 164 cm high, 874 cm with trim boom extended; 77 cm in diameter with solar panels and magnetometer boom extended; 722 cm length along flight path—magnetometer boom and solar array deployed. Spacecraft 3-axis stabilized. Weight: 183 kg.	351.9 578.4 93.90 96.79	Launched successfully by NASA. Third in a series of low-cost modular designated satellites, designated Applications Explorer Missions. Star cameras turned on and vector magnetometer measurements begun next day. Nov. 1 sensor boom deployed to planned length of 6 m, and scalar magnetometer measurements initiated.
Nov. 21 DSCS II-13 98A Titan IIIC	Objective: Military communications. Spacecraft: Drum-shaped 2.7 m in diameter, 1.8 m high, with two dish antennas 1.1 m each, giving an overall length of 4 m. Solar cells provide 535 watts at launch. Communications repeater in X-band has 410 MHz bandwidth, 1300 circuits, power output of 20 watts from each of two traveling wave tubes. Has both Earth coverage and narrow coverage antennas. Weight: 565 kg.	35,789 35,609 1431.0 2.5	Still in orbit.
Nov. 21 DSCS II-14 98B Titan IIIC	Objective: Military communications. Spacecraft: Same as preceding.	36,375 35,788 1451.0 2.5	Still in orbit.

Successful U.S. Launches—1979

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period Inclination to equator (degrees)	Remarks
Dec. 7 RCA 101A Delta	Objective: To launch spacecraft into successful transfer orbit. Satellite to provide television, voice communications, and high-speed data transmission to all 50 states. Spacecraft: Box shape, 120 cm by 162 cm for the base-plate and 117 cm for main body height. Each bifold solar array is 155 cm by 226 cm. Solar panels fold against transponder body during launch. Four-reflector antenna. Three axis-stabilized. Weight: 895 kg.	36,124 166.3 637 23.8	Third in a series of satellites, successfully launched by NASA for RCA American Communications, Inc. Spacecraft supposed to be placed over equator at 132° west longitude. Contact with satellite lost when apogee boost motor fired Dec. 10. Subsequent attempts to locate spacecraft have been unsuccessful.

U.S. Applications Satellites 1975-1979

Date	Name	Launch Vehicle	Remarks
COMMUNICATIONS			
May 7, 1975	Anik 3 (Telesat 3)	Thor-Delta (TAT)	Launched for Canada.
May 22, 1975	Intelsat IV (F-1)	Atlas-Centaur	Eighth in high-capacity series. Positioned over Indian Ocean.
Aug. 27, 1975	Symphonie 2	Thor-Delta (TAT)	Launched for France and West Germany. Positioned over the Atlantic.
Sep. 26, 1975	Intelsat IV-A (F-1)	Atlas-Centaur	First of a new series double the capacity of its predecessors. Positioned over the Atlantic.
Dec. 13, 1975	RCA-Satcom-1	Thor-Delta (TAT)	Launched for RCA as first of their communications satellite series. Positioned over the Pacific.
Jan. 17, 1976	CTS 1	Thor-Delta (TAT)	Canadian-U.S., most powerful experimental satellite.
Jan. 30, 1976	Intelsat IV-A (F-2)	Thor-Delta (TAT)	Positioned over Atlantic.
Feb. 19, 1976	Marisat 1	Thor-Delta (TAT)	For maritime use by Comsat, over the Atlantic.
Mar. 15, 1976	LES 8/9	Titan IIIC	Experimental satellites with radioisotope power sources.
Mar. 26, 1976	RCA-Satcom 2	Thor-Delta (TAT)	Second of three.
Apr. 22, 1976	NATO IIIA	Thor-Delta (TAT)	First of new series.
May 13, 1976	Comstar 1	Atlas-Centaur	Placed over Pacific for AT&T by Comsat.
June 10, 1976	Marisat 2	Thor-Delta (TAT)	For maritime use by Comsat, over the Pacific.
July 8, 1976	Palapa 1	Thor-Delta (TAT)	Indonesian domestic communications.
July 22, 1976	Comstar 2	Thor-Delta (TAT)	Placed south of the United States for AT&T by Comsat.
Oct. 14, 1976	Marisat 3	Thor-Delta (TAT)	Placed over Indian Ocean.
Jan. 28, 1977	NATO IIIB	Thor-Delta (TAT)	Second of a new series.
Mar. 10, 1977	Palapa 2	Thor-Delta (TAT)	Indonesian domestic communications.
May 12, 1977	DSCS II-7,8	Titan IIIC	Defense communications (dual launch).
May 26, 1977	Intelsat IV-A (F-4)	Atlas-Centaur	Positioned over Atlantic.
Aug. 25, 1977	Sirio	Thor-Delta (TAT)	Italian experiment.
Dec. 15, 1977	Sakura	Thor-Delta (TAT)	Japanese experiment.
Jan. 7, 1978	Intelsat IV-A (F-3)	Atlas-Centaur	Positioned over Indian Ocean.
Feb. 9, 1978	Fltsatcom 1	Atlas-Centaur	First of a new Defense series.
Mar. 5, 1978	Oscar 8	Thor-Delta (TAT)	Secondary payload with Landsat 3, replacement for Oscar 6 for amateur radio communications.
Mar. 31, 1978	Intelsat IV-A (F-6)	Atlas-Centaur	Positioned over Indian Ocean.
Apr. 7, 1978	BSE	Thor-Delta (TAT)	Japanese experimental direct-broadcast satellite for television; named Yuri; domestic satellite.
May 11, 1978	OTS 2	Thor-Delta (TAT)	European Space Agency experimental relay satellite; domestic satellite.
June 29, 1978	Comstar 3	Atlas-Centaur	Positioned south of U.S. over the equator by Comsat; domestic satellite.
Nov. 19, 1978	NATO IIIC	Thor-Delta (TAT)	Final one of this military series.
Dec. 14, 1978	DSCS II-11,12	Titan IIIC	Defense communications (dual launch).
Dec. 16, 1978	Anik 4 (Telesat D)	Thor-Delta (TAT)	Launched for Canada; domestic satellite.
May 4, 1979	Fltsatcom 2	Atlas-Centaur	Second of a new DoD series.
Aug. 9, 1979	Westar 3	Thor-Delta (TAT)	Launched for the Western Union Co. as part of their domestic communications links.
Nov. 21, 1979	DSCS II-13,14	Titan IIIC	Defense communications (dual launch).
Dec. 2, 1979	RCA-Satcom 3	Thor-Delta (TAT)	Launched for RCA, but contact lost during orbit circularization.
WEATHER OBSERVATION*			
Feb. 6, 1975	SMS 2	Thor-Delta (TAT)	Second full-time weather satellite in synchronous orbit.
June 12, 1975	Nimbus 6	Thor-Delta (TAT)	To build numerical models for Global Atmospheric Research Program.
Oct. 16, 1975	Goes 1	Thor-Delta (TAT)	First fully operational synchronous-orbit weather satellite.
July 29, 1976	Noaa 5 (ITOS-H)	Thor-Delta (TAT)	Second generation operational satellite.
June 16, 1977	Goes 2	Thor-Delta (TAT)	Second of this series.
July 14, 1977	Himawari	Thor-Delta (TAT)	Japanese geosynchronous satellite.
Nov. 23, 1977	Meteosat	Thor-Delta (TAT)	European Space Agency geosynchronous satellite.
May 1, 1978	AMS 3	Thor-Burner 2	A DoD meteorological satellite.
June 16, 1978	Goes 3	Thor-Delta (TAT)	Third of this series for NOAA.
Oct. 13, 1978	Tiros-N	Atlas F	First of a third generation for NOAA, also experimental satellite for NASA.
Oct. 24, 1978	Nimbus 7	Thor-Delta (TAT)	Last of this experimental series for NASA.
June 6, 1979	AMS-4	Atlas F	A DoD meteorological satellite.
June 27, 1979	Noaa 6	Atlas F	Like the current DoD meteorological satellites.
EARTH OBSERVATION			
Jan. 22, 1975	Landsat 2	Thor-Delta (TAT)	Second experimental Earth resources technology satellite. Acquired synoptic multi-spectral repetitive images that are proving useful in such disciplines as agriculture and forestry resources, mineral and land resources, land use, water resources, marine resources, mapping and charting, and the environment.
Mar. 5, 1978	Landsat 3	Thor-Delta (TAT)	Third experimental Earth-resources satellite.
Apr. 26, 1978	HCMM (AEM-1)	Scout	Experimental, low-cost, limited-function heat-capacity mapping mission for Earth resources.

* Does not include Department of Defense weather satellites which are not individually identified by launch.

U.S. Applications Satellites 1975-1979

Date	Name	Launch Vehicle	Remarks
June 27, 1978	Seasat 1	Atlas F	Proof-of-concept oceanographic-phenomena data-collection satellite.
GEODESY			
Apr. 9, 1975	Geos 3	Thor-Delta (TAT)	To measure geometry and topography of ocean surface.
May 4, 1976	Lageos	Thor-Delta (TAT)	Laser geodynamic satellite.
NAVIGATION			
Oct. 12, 1975	Tip 2	Scout	Transit Improvement Program.
Sep. 1, 1976	Tip 3	Scout	Transit Improvement Program.
June 23, 1977	NTS 2	Atlas F	Forerunner of Navstar Global Positioning System.
Oct. 28, 1977	Transit	Scout	Developmental model.
Feb. 22, 1978	Navstar 1	Atlas F	Global Positioning System satellite.
May 13, 1978	Navstar 2	Atlas F	Global Positioning System satellite.
Oct. 7, 1978	Navstar 3	Atlas F	Global Positioning System satellite.
Dec. 11, 1978	Navstar 4	Atlas F	Global Positioning System satellite.

APPENDIX B-2

U.S.-Launched Scientific Payloads 1975-1979

Date	Name	Launch Vehicle	Remarks
May 7, 1975	SAS-C (Explorer 53)	Scout	Measure x-ray emission of discrete extragalactic sources. (Italian-launched.)
June 21, 1975	Oso 8	Thor-Delta (TAT)	To study minimum phase of solar cycle.
Aug. 9, 1975	COS-B	Thor-Delta	Extraterrestrial gamma radiation studies. (ESA European satellite.)
Oct. 6, 1975	Atmosphere (Explorer 54)	Thor-Delta	Photochemical processes in absorption of solar energy.
Nov. 20, 1975	Atmosphere (Explorer 55)	Thor-Delta	Photochemical processes in absorption of solar energy. Measure spatial distribution of ozone.
Mar. 15, 1976	Solrad HiA/HiB	Titan IIIC	Measure radiation and particles at close to 120,000 km circular.
May 22, 1976	P-76-5	Scout	Plasma effects on radar and communications.
July 8, 1976	SESP 74-2	Titan IIID	Particle measurements up to 8000 km.
Apr. 20, 1977	Geos	Thor-Delta (TAT)	European Space Agency, study of magnetic and electric fields from geosynchronous orbit (not attained.)
Aug. 12, 1977	HEAO 1	Atlas-Centaur	X-ray and gamma ray astronomy.
Oct. 22, 1977	ISEE 1,2	Thor-Delta (TAT)	Magnetosphere and solar wind measurements (for NASA and European Space Agency respectively).
Jan. 26, 1978	IUE	Thor-Delta (TAT)	Ultraviolet observation of astronomical phenomena, in elliptical geosynchronous orbit.
July 14, 1978	Geos 2	Thor-Delta (TAT)	European studies of magnetosphere, in geosynchronous orbit.
Aug. 12, 1978	ISEE 3	Thor-Delta (TAT)	International Sun-Earth Explorer, in halo orbit near Earth-Sun libration point.
Oct. 24, 1978	Cameo	Thor-Delta (TAT)	Barium and lithium cloud experiments, carried in rocket body of Nimbus 7 launcher.
Nov. 13, 1978	HEAO 2	Atlas-Centaur	High-resolution observations of astronomical x-ray sources.
Jan. 30, 1979	Scatha	Thor-Delta (TAT)	Measurement of sources of electric charge buildup on spacecraft.
Feb. 18, 1979	Sage	Scout	Measurement of stratospheric aerosols and ozone.
Feb. 24, 1979	Solwind	Atlas F	Measurement of solar wind, electron buildup in polar regions, aerosols, and ozone.
June 6, 1979	Ariel 6	Scout	Measurement of cosmic radiation (United Kingdom payload).
Sep. 20, 1979	HEAO 3	Atlas-Centaur	Gamma and cosmic ray emissions.
Oct. 30, 1979	Magsat	Scout	Detailed current description of Earth's magnetic field and of sources of variations.

U.S.-Launched Space Probes 1975-1979

Date	Name	Launch Vehicle	Remarks
Aug. 20, 1975	Viking 1	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Chryse, while Orbiter circled the planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of the atmosphere.
Sep. 9, 1975	Viking 2	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Utopia, while Orbiter circled the planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of the atmosphere.
Jan. 15, 1976	Helios 2	Titan IIIE-Centaur	Flew in highly elliptical orbit to within 41 million km of the Sun, measuring solar wind, corona, electrons, and cosmic rays. Payload had same West German and U.S. experiments as Helios 1 plus a cosmic-ray burst detector.
Aug. 20, 1977	Voyager 2	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Was to swing around Jupiter in July 1979 and arrive at Saturn in 1981, possibly going on to Uranus by 1986.
Sep. 5, 1977	Voyager 1	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Passing Voyager 2 on the way, was to swing around Jupiter in Mar. 1979 and arrive at Saturn in Nov. 1980.
May 20, 1978	Pioneer Venus 1	Atlas-Centaur	Venus orbiter; achieved Venus orbit Dec. 4, returning imagery and data.
Aug. 8, 1978	Pioneer Venus 2	Atlas-Centaur	Carried 1 large, 3 small probes plus spacecraft bus; all descended through Venus atmosphere Dec. 9, returned data.

History of U.S. and Soviet Manned Space Flights

Spacecraft	Launch Date	Crew	Flight time	Highlights
Vostok 1	Apr. 12, 1961	Yuri A. Gagarin	1 h 48 min.	First manned flight.
Mercury-Redstone 3	May 5, 1961	Alan B. Shepard, Jr.	15 min.	First U.S. flight; suborbital.
Mercury-Redstone 4	July 21, 1961	Virgil I. Grissom	16 min.	Suborbital; capsule sank after landing.
Vostok 2	Aug. 6, 1961	Gherman E. Titov	25 h 18 min.	First flight exceeding 24 h.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	4 h 55 min.	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	4 h 56 min.	Landed 400 km beyond target.
Vostok 3	Aug. 11, 1962	Andrian G. Nikolayev	94 h 22 min.	First dual mission (with Vostok 4).
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	70 h 57 min.	Came within 6 km of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	9 h 13 min.	Landed 8 km from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	34 h 20 min.	First U.S. flight exceeding 24 h.
Vostok 5	June 14, 1963	Valeriy F. Bykovskiy	119 h 6 min.	Second dual mission (with Vostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	70 h 50 min.	First woman in space; within 5 km of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Dr. Boris G. Yegorov	24 h 17 min.	First 3-man crew.
Voskhod 2	Mar. 18, 1965	Aleksey A. Leonov Pavel I. Belyayev	26 h 2 min.	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	4 h 53 min.	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, II	97 h 56 min.	21-min. extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	190 h 55 min.	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	330 h 35 min.	Longest-duration manned flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	25 h 51 min.	Rendezvous within 30 cm of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	10 h 41 min.	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	72 h 21 min.	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	70 h 47 min.	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	71 h 17 min.	First initial-orbit docking; first tethered flight; highest Earth-orbit altitude (1372 km).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	94 h 35 min.	Longest extravehicular activity to date (Aldrin, 5 h 37 min).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	26 h 37 min.	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	260 h 9 min.	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgiy Beregovoy	94 h 51 min.	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	147 h 1 min.	First manned orbit(s) of Moon; first manned departure from Earth's sphere of influence; highest speed ever attained in manned flight.
Soyuz 4	Jan. 14, 1969	Vladimir Shatalov	71 h 23 min.	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris Volynov Aleksey Yeliseyev Yevgeniy Khrunov	72 h 56 min.	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	241 h 1 min.	Successfully simulated in Earth orbit operation of lunar module to landing and take-off from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	192 h 3 min.	Successfully demonstrated complete system including lunar module descent to 14,300 m from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	195 h 9 min.	First manned landing on lunar surface and safe return to Earth. First return of rock and soil samples to Earth, and manned deployment of experiments on lunar surface.
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy Kubasov	118 h 42 min.	Soyuz 6, 7, and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and Earth and celestial observation.
Soyuz 7	Oct. 12, 1969	Anatoliy Filipchenko Vladislav Volkov Viktor Gorbato	118 h 41 min.	
Soyuz 8	Oct. 13, 1969	Vladimir Shatalov Aleksey Yeliseyev	118 h 50 min.	

History of U.S. and Soviet Manned Space Flights

Spacecraft	Launch Date	Crew	Flight time	Highlights
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	244 h 36 min.	Second manned lunar landing. Continued manned exploration and retrieved parts of Surveyor III spacecraft which landed in Ocean of Storms on Apr. 19, 1967.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	142 h 55 min.	Mission aborted due to explosion in the service module. Ship circled Moon, with crew using LEM as "lifeboat" until just prior to reentry.
Soyuz 9	June 1, 1970	Andrian G. Nikolayev Vitaliy I. Sevastianov	424 h 59 min.	Longest manned space flight to date, lasting 17 days 16 h 59 min.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	216 h 2 min.	Third manned lunar landing. Mission demonstrated pinpoint landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir Shatalov Aleksy Yeliseyev Nikolai Rukavishnikov	47 h 46 min.	Docked with Salyut 1, but crew did not board space station launched Apr. 19. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy Timofeyevich Dobrovolskiy Vladislav Nikolayevich Volkov	570 h 22 min.	Docked with Salyut 1 and Soyuz 11 crew occupied space station for 22 days. Crew perished during final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	Viktor Ivanovich Patsayev David R. Scott Alfred M. Worden James Bensen Irwin	295 h 12 min.	Fourth manned lunar landing and first Apollo "J" series mission which carry the Lunar Roving Vehicle. Worden's in-flight EVA of 38 min 12 s was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly, II	265 h 51 min.	Fifth manned lunar landing, with Lunar Roving Vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	301 h 52 min.	Sixth and final Apollo manned lunar landing, again with roving vehicle.
Skylab 2	May 25, 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	627 h 50 min.	Docked with Skylab 1 for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	1427 h 9 min.	Docked with Skylab 1 for over 59 days.
Soyuz 12	Sept. 27, 1973	Vasilij Lazarev Oleg Makarov	47 h 16 min.	Checkout of improved Soyuz.
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	2017 h 16 min.	Docked with Skylab 1 in long-duration mission; last of Skylab program.
Soyuz 13	Dec. 18, 1973	Petr Klimuk Valentin Lebedev	188 h 55 min.	Astrophysical, biological, and Earth resources experiments.
Soyuz 14	July 3, 1974	Pavel Popovich Yuriy Artyukhin	377 h 30 min.	Docked with Salyut 3 and Soyuz 14 crew occupied space station for over 14 days.
Soyuz 15	Aug. 26, 1974	Gennadiy Sarafanov Lev Demin	48 h 12 min.	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatolij Filipchenko Nikolai Rukavishnikov	142 h 24 min.	Test of ASTP configuration.
Soyuz 17	Jan. 10, 1975	Aleksy Gubarev Georgiy Grechko	709 h 20 min.	Docked with Salyut 4 and occupied station during a 29-day flight.
Anomaly	Apr. 5, 1975	Vasiley Lazarev Oleg Makarov	20 min.	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr Klimuk Vitaliy Sevastianov	1511 h 20 min.	Docked with Salyut 4 and occupied station during a 63-day mission.
Soyuz 19	July 15, 1975	Aleksy Leonov Valeriy Kubasov	142 h 31 min.	Target for Apollo in docking and joint experiments ASTP mission.
Apollo	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	217 h 28 min.	Docked with Soyuz 19 in joint experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris Volynov Vitaliy Zholobov	1182 h 24 min.	Docked with Salyut 5 and occupied station during 49-day flight.
Soyuz 22	Sep. 15, 1976	Valeriy Bykovskiy Vladimir Aksenov	189 h 54 min.	Earth resources study with multispectral camera system.
Soyuz 23	Oct. 14, 1976	Vyacheslav Zudov Valeriy Rozhdestvenskiy	48 h 6 min.	Failed to dock with Salyut 5.
Soyuz 24	Feb 7, 1977	Viktor Gorbato Yuriy Glazkov	425 h 23 min.	Docked with Salyut 5 and occupied station during 18-day flight.
Soyuz 25	Oct. 9, 1977	Vladimir Kovalenok Valeriy Ryumin	48 h 46 min.	Failed to achieve hard dock with Salyut 6 station.

History of U.S. and Soviet Manned Space Flights

Spacecraft	Launch Date	Crew	Flight time	Highlights
Soyuz 26	Dec. 10, 1977	Yuriy Romanenko Georgiy Grechko	898 h 6 min.	Docked with Salyut 6. Crew returned in Soyuz 27; crew duration 2314 h.
Soyuz 27	Jan. 10, 1978	Vladimir Dzhanibekov Oleg Makarov	1514 h.	Docked with Salyut 6. Crew returned in Soyuz 26; crew duration 142 h 59 min.
Soyuz 28	Mar. 2, 1978	Aleksey Gubarev Vladimir Remek	190 h 17 min.	Docked with Salyut 6. Remek was 1st Czech cosmonaut to orbit.
Soyuz 29	June 15, 1978	Vladimir Kovalenok Aleksandr Ivanchenkov	1911 h 23 min.	Docked with Salyut 6. Crew returned in Soyuz 31; crew duration 3350 h 48 min.
Soyuz 30	June 27, 1978	Petr Klimuk Miroslaw Heraszewski	190 h 4 min.	Docked with Salyut 6. Heraszewski was 1st Polish cosmonaut to orbit.
Soyuz 31	Aug. 26, 1978	Valeriy Bykovskiy Sigmund Jahn	1628 h 14 min.	Docked with Salyut 6. Crew returned in Soyuz 29; crew duration 188 h 49 min. Jahn was 1st German Democratic Republic cosmonaut to orbit.
Soyuz 32	Feb. 25, 1979	Vladimir Lyakhov Valeriy Ryumin	2596 h 24 min.	Docked with Salyut 6. Crew returned in Soyuz 34; crew duration 4200 h 36 min, or 175 days.
Soyuz 33	Apr. 10, 1979	Nikolay Rukavishnikov Georgiy Ivanov	47 h 01 min.	Failed to achieve docking with Salyut 6 station. Ivanov was first Bulgarian cosmonaut to orbit.
Soyuz 34	June 6, 1979	(unmanned at launch)	1770 h 17 min.	Docked with Salyut 6, later served as a ferry for Soyuz 32 crew while Soyuz 32 returned unmanned.

APPENDIX D

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant ³	Thrust (in kilo- newtons)	Max. dia. (m)	Max. Payload (kg)			
					Height (m)	555-km orbit	Escape	First launch
Scout	1. Algol IIIA	Solid	481.0	1.12	21.95	186 ⁴	38.6 ⁴	1972(60) ¹
	2. Castor IIA	Solid	281.0					
	3. Antares III	Solid	83.1					
	4. Altair III	Solid	26.2					
Thor-Delta 2900 series	1. Thor plus 9 TX 354-5	LOX/RP-1 Solid	911.9 440.4 ²	2.44	35.36	1769 ⁴	476 ⁴	1973(60) ¹
	2. Delta (DSV-3)	N ₂ O ₄ /Aerozine	45.8					
	3. TE 364-4	Solid	66.7					
Atlas F/TE 364-4	1. Atlas booster & sustainer	LOX/RP-1	1970.6	3.05	25.91	1497 ⁴		1977(60) ¹
	2. TE 364-4	Solid	66.7					
Atlas-Agena	1. Atlas booster & (SLV/3A)	LOX/RP-1	2237.5	3.05	40.54	2722 ⁴	454 ⁴	1968(60) ¹
	2. Agena	IRFNA/UDMH	71.2					
Titan IIIB-Agena	1. LR-87	N ₂ O ₄ /Aerozine	2353.1	3.05	48.46	3614	3727 ⁵	1966
	2. LR-91	N ₂ O ₄ /Aerozine	444.8					
	3. Agena	IRFNA/UDMH	71.2					
Titan IIIC	1. Two 5-segment 3.05-m dia.	Solid	10413.3	3.05	40.54	—	1464 ⁷	1965
	2. LR-87	N ₂ O ₄ /Aerozine	2353.1					
	3. LR-91	N ₂ O ₄ /Aerozine	444.8					
	4. Transtage	N ₂ O ₄ /Aerozine	71.2					
Titan III(23)D	1. Two 5-segment 3.05-m dia.	Solid	10413.3	3.05	46.94	11,182 ⁸		1971
	2. LR-87	N ₂ O ₄ /Aerozine	2353.1					
	3. LR-91	N ₂ O ₄ /Aerozine	444.8					
Titan III(34)D	1. Two 5½-segment 3.05-m dia.	Solid	11555.6	3.05	49.13	12,545 ⁸		1981
	2. LR-87	N ₂ O ₄ /Aerozine	2353.1					
	3. LR-91	N ₂ O ₄ /Aerozine	444.8					
Titan III(34)D/IUS	1. Two 5½-segment 3.05-m dia.	Solid	11555.6	3.05	48.00	1818 ⁹	1818 ⁸	1981
	2. LR-87	N ₂ O ₄ /Aerozine	2353.1					
	3. LR-91	N ₂ O ₄ /Aerozine	444.8					
	4. IUS 1st Stage	Solid	191.3					
	5. IUS 2nd Stage	Solid	71.2					
Thor LV-2F	1. Thor	LOX/RP-1	756.2	2.44	23.77	512 ¹⁰		1976(66) ¹
	2. TE 364-4	Solid	66.7					
	3. TE 364-15	Solid	44.5					
Thor SLV-2A/Block 5D-2	1. Thor plus 3 TX 354-5	LOX/RJ-1 Solid	756.2 689.5 ²	2.44	24.23	653 ¹⁰		1980(63) ¹
	2. TE 364-4	Solid	66.7					
	3. TE 364-15	Solid	44.5					

¹ The date of first launch applies to this latest modification with a date in parentheses for the initial version.

² Set of 3.

³ Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene—Lox/RP,RJ; Solid propellant combining in a single mixture both fuel and oxidizer—Solid; Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethylhydrazine—IRFNA/UDMH; Nitrogen Tetroxide and UDMH/N₂H₄—N₂O₄/Aerozine.

⁴ Due east launch.

⁵ Polar launch 185 km.

⁶ Polar 185 km (nominal).

⁷ Synchronous equatorial (nominal).

⁸ Polar 185 km (current estimate).

⁹ Synchronous equatorial (current estimate).

¹⁰ Polar 833 km (from WTR).

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY—BUDGET AUTHORITY

(In millions of dollars)

Fiscal Year	NASA		Defense	Energy	Com- merce	Interior	Agricul- ture	NSF	Total Space
	Total	Space ¹							
1959	330.9	260.9	489.5	34.3	...	...	...	...	784.7
1960	523.6	461.5	560.9	43.3	...	...	...	.1	1065.8
1961	964.0	926.0	813.9	67.7	...	...	...	.6	1808.2
1962	1824.9	1796.8	1298.2	147.8	50.7	...	...	1.3	3294.8
1963	3673.0	3626.0	1549.9	213.9	43.2	...	...	1.5	5434.5
1964	5099.7	5016.3	1599.3	210.0	2.8	...	...	3.0	6831.4
1965	5249.7	5137.6	1573.9	228.6	12.2	...	...	3.2	6955.5
1966	5174.9	5064.5	1688.8	186.8	26.5	...	...	3.2	6969.8
1967	4965.6	4830.2	1663.6	183.6	29.3	...	...	2.8	6709.5
1968	4587.3	4430.0	1921.8	145.1	28.1	.2	.5	3.2	6528.9
1969	3990.9	3822.0	2013.0	118.0	20.0	.2	.7	1.9	5975.8
1970	3745.8	3547.0	1678.4	102.8	8.0	1.1	.8	2.4	5340.5
1971	3311.2	3101.3	1512.3	94.8	27.4	1.9	.8	2.4	4740.9
1972	3306.6	3071.0	1407.0	55.2	31.3	5.8	1.6	2.8	4574.7
1973	3406.2	3093.2	1623.0	54.2	39.7	10.3	1.9	2.6	4824.9
1974	3036.9	2758.5	1766.0	41.7	60.2	9.0	3.1	1.8	4640.3
1975	3229.1	2915.3	1892.4	29.6	64.4	8.3	2.3	2.0	4914.3
1976	3550.3	3225.4	1983.3	23.3	71.5	10.4	3.6	2.4	5319.9
T. Q. ²	931.8	849.2	460.4	4.6	22.2	2.6	.9	.6	1340.5
1977	3817.8	3440.2	2411.9	21.7	90.8	9.5	6.3	2.4	5982.8
1978	4060.1	3622.9	2728.8	34.4	102.8	9.7	7.7	2.4	6508.7
1979	4595.5	4030.4	3211.3	58.6	98.4	9.9	8.2	2.4	7419.2
1980 Est.	5266.9	4696.6	4003.4	54.2	90.7	11.7	13.1	2.4	8872.1
1981 Est.	5514.6	4989.1	4910.7	50.8	92.9	12.1	15.7	2.4	10073.7

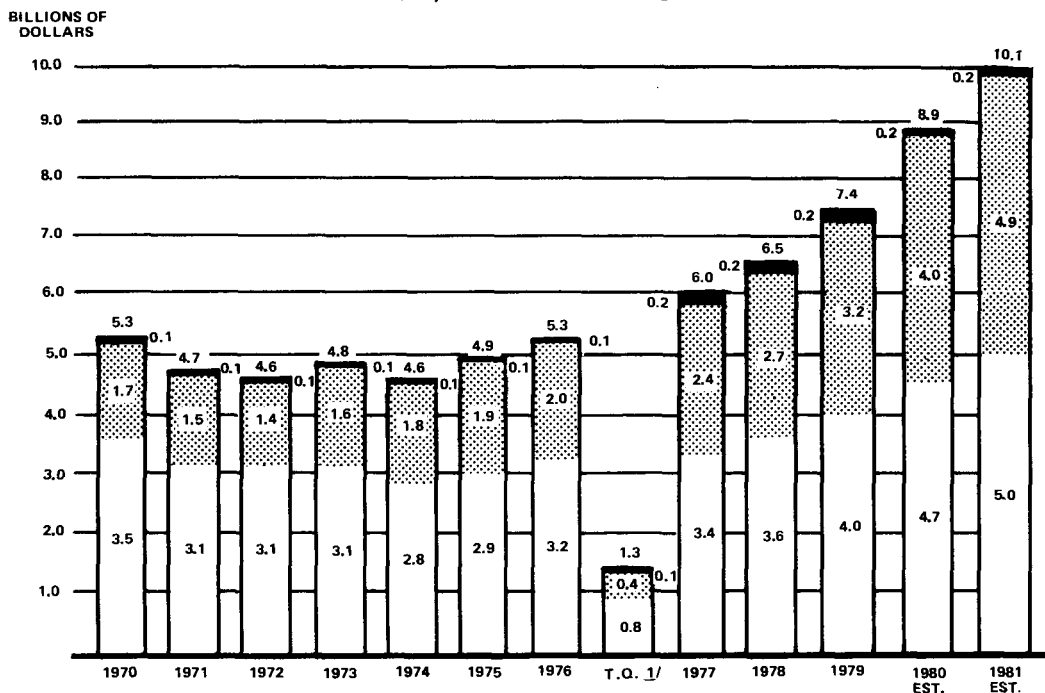
¹ Excludes amounts for air transportation (subfunction 402).

Source: Office of Management and Budget.

² T. Q.—Transitional Quarter.

U. S. Space Budget-Budget Authority 1970-1981

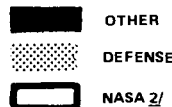
(May not add due to rounding)



1/ T. Q. - TRANSITIONAL QUARTER

2/ EXCLUDES AMOUNTS FOR AIR TRANSPORTATION

SOURCE: OFFICE OF MANAGEMENT AND BUDGET



Space Activities Budget

(In millions of dollars)

	Budget Authority			Outlays		
	1979 Actual	1980 Est.	1981 Est.	1979 Actual	1980 Est.	1981 Est.
Federal space programs:						
NASA ¹	4030.4	4696.6	4989.1	3743.9	4471.4	4675.1
Defense	3211.3	4003.4	4910.7	2891.8	3472.7	4277.3
Energy	58.6	54.2	50.8	54.7	58.4	50.7
Commerce	98.4	90.7	92.9	97.4	89.8	91.9
Interior	9.9	11.7	12.1	9.9	11.2	11.8
NSF	2.4	2.4	2.4	2.4	2.4	2.4
Agriculture	8.2	13.1	15.7	8.2	13.1	15.7
Total	7419.2	8872.1	10073.7	6808.3	8119.0	9124.9
NASA:						
Space flight	2432.6	2846.9	3135.7	2216.8	2745.1	2945.7
Space science, applications, and technology	1224.2	1415.3	1403.7	1153.1	1315.8	1309.5
Air transportation	519.1	570.3	525.5	443.3	528.3	537.5
Supporting operations	382.9	437.3	452.8	383.3	413.4	423.0
Less receipts	-9.3	-2.9	-3.1	-9.3	-2.9	-3.1
Total NASA	4549.5	5266.9	5514.6	4187.2	4999.7	5212.6

¹ Excludes amounts for air transportation.

Source: Office of Management and Budget.

Aeronautics Budget

(In millions of dollars)

	Budget Authority		
	1979 Actual	1980 Est.	1981 Est.
Federal aeronautics programs:			
NASA ¹	519.1	570.3	525.5
Department of Defense ²	2239.7	2223.2	2149.1
Department of Transportation ³	90.8	92.0	87.0
Total	2849.6	2885.5	2761.6

¹ Research and Development, Construction of Facilities, Research and Program Management.² Research, Development, Testing and Evaluation of aircraft and related equipment.³ Federal Aviation Administration Research and Development.

Source: Office of Management and Budget.

White House Fact Sheet

November 20, 1979

Management of U.S. Civilian Remote Sensing Activities

The President today announced the designation of the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) to manage all operational civilian remote sensing activities from space. This designation is one of several policy decisions announced today after a review of civilian space policy mandated by a Presidential Directive in October, 1978.

Early in his administration, the President directed a comprehensive review of space policy. The review, completed in May, 1978, resulted in a Presidential Directive that established a national space policy framework. It created a Policy Review Committee on Space, chaired by the Director of the Office of Science and Technology Policy, Frank Press. One of the tasks of the Policy Review Committee has been to assess the Nation's future civil space remote sensing requirements. That review was the basis for the policy decisions announced today.

Designation of a single agency, NOAA, to manage all civil operational satellite activities will lend itself to further integration and potential cost saving in the future. NOAA's experience in successfully operating and managing three generations of weather satellites prepares it to assume the responsibility for land remote sensing in addition to its ongoing atmospheric and oceanic activities. NOAA's first action will be to develop a transition plan in coordination with other appropriate agencies for moving to a fully integrated satellite-based land remote sensing program.

Initially, our operational land remote sensing efforts will rely on experience derived from the Landsat program. Landsat was begun in 1972 by NASA as a satellite effort specifically designed to observe surface features of the earth.

The President's decision establishes a three-part framework to serve remote sensing activities:

- Integration of civilian operational activities under NOAA.
- Joint or coordinated civil/military activities where both parties' objectives can be best met through this approach.
- Separate defense activities which have no civilian counterpart.

Other space policy decisions developed by this review and announced today are:

- The Commerce Department will seek ways to further private sector opportunities in civil land remote sensing activities, through joint ventures with industry, a quasi-government corporation, leasing, etc., with the goal of eventual operation of these activities by the private sector.

- We will continue the policy of providing Landsat data to foreign users, and promoting development of complementary and cooperative nationally operated satellite systems so as to increase benefits for all nations.

- The Department of Commerce will establish and chair a Program Board for continuing federal coordination and regulation of civil remote sensing activities. The involved federal organizations will be represented (i.e., the Department of Defense, Interior, Agriculture, State, Transportation, and Energy, and NASA, CIA, AID, and EPA). The National Governors' Association and the National Conference of State Legislatures will be invited to participate.

—Separate weather programs for the military and civil sectors will be maintained under the Departments of Defense and Commerce because of their differing needs. We will continue procurement of current spacecraft until development of a new system design is justified. Future polar orbiting satellite development and procurement will be jointly undertaken by Defense, Commerce and NASA to maximize technology-sharing and minimize cost.

—Ocean observations from space can meet common civil and military data requirements. Accordingly, if we decide to develop ocean satellites, joint Defense/Commerce/NASA management of the program will be pursued.

The United Nations Moon Treaty

The Moon Treaty has been under discussion since late 1971 when the General Assembly adopted resolution 2779, in which it took note of a draft treaty submitted by the U.S.S.R. and requested the Committee on the Peaceful Uses of Outer Space (COPUOS) and its legal Subcommittee (LSC) to consider the question of the elaboration of a draft international treaty concerning the Moon on a priority basis.

The draft Moon Treaty is based to a considerable extent on the 1967 Outer Space Treaty. Indeed, the discussion in the Outer Space Committee confirmed the understanding that the Moon Treaty in no way derogates from or limits the provisions of the 1967 Outer Space Treaty.

The draft Moon Treaty also is, in its own right, a meaningful advance in the codification of international law dealing with outer space, containing obligations of both immediate and long-term application to such matters as the safeguarding of human life on celestial bodies, the promotion of scientific investigation and the exchange of information relative to and derived from activities on celestial bodies, and the enhancement of opportunities and conditions for evaluation, research, and exploitation of the natural resources of celestial bodies.

The General Assembly, by consensus, opened the treaty for signature on December 5, 1979.

This appendix presents the text of the draft treaty in the left column on each page; in the right column, opposite the appropriate sections of the text, are some comments by the Department of State on the attitude of the United States regarding particular provisions.

Draft agreement governing the activities of States on the moon and other celestial bodies.

The States Parties to this Agreement,

Noting the achievements of States in the exploration and use of the moon and other celestial bodies,

Recognizing that the moon, as a natural satellite of the earth, has an important role to play in the exploration of outer space,

Determined to promote on the basis of equality the further development of co-operation among States in the exploration and use of the moon and other celestial bodies,

Desiring to prevent the moon from becoming an area of international conflict,

Bearing in mind the benefits which may be derived from the exploitation of the natural resources of the moon and other celestial bodies,

Recalling the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, the Convention on International Liability for Damage Caused by Space Objects, and the Convention on Registration of Objects Launched into Outer Space,

Taking into account the need to define and develop the provisions of these international instruments in relation to the moon and other celestial bodies, having regard to further progress in the exploration and use of outer space,

Have agreed on the following:

Article I

1. The provisions of this Agreement relating to the moon shall also apply to other celestial bodies within the solar system, other than the earth, except in so far as specific legal norms enter into force with respect to any of these celestial bodies.

2. For the purposes of this Agreement reference to the moon shall include orbits around or other trajectories to or around it.

3. This Agreement does not apply to extraterrestrial materials which reach the surface of the earth by natural means.

There has been considerable discussion of Article I of the draft treaty. The United States accepts the Outer Space Committee's conclusions as to this article—namely, first, that references to the moon are intended also to the references to other celestial bodies within our solar system other than the earth; secondly, that references to the moon's natural resources are intended to comprehend those natural resources to be found on these celestial bodies; and, thirdly, that the trajectories and orbits referred to in Article I, paragraph 2, do not include trajectories and orbits of space objects between the earth and earth orbit or in earth orbit only. In regard to the phrase "earth orbit only", the fact that a space object in earth orbit also is in orbit around the sun does not bring space objects which are only in earth orbit within the scope of this treaty.

Article II

All activities on the moon, including its exploration and use, shall be carried out in accordance with international law, in particular the Charter of the United Nations, and taking into account the Declaration on Principles of International Law concerning Friendly Relations and Cooperation among States in accordance with the Charter of the United Nations, adopted by the General Assembly on 24 October 1970, in the interest of maintaining international peace and security and promoting international co-operation and mutual understanding, and with due regard to the corresponding interests of all other States Parties.

Article III

1. The moon shall be used by all States Parties exclusively for peaceful purposes.

2. Any threat or use of force or any other hostile act on the moon is prohibited. It is likewise prohibited to use the moon in order to commit any such act or to engage in any such threat in relation to the earth, the moon, spacecraft, the personnel of spacecraft or man-made objects.

3. States Parties shall not place in orbit around or other trajectory to or around the moon objects carrying nuclear weapons or any other kinds of weapons of mass destruction or place or use such weapons on or in the moon.

4. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on the moon shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration and use of the moon shall also not be prohibited.

Article IV

1. The exploration and use of the moon shall be the province of all mankind and shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development. Due regard shall be paid to the interest of present and future generations as well as to the need to promote higher standards of living conditions of economic and social progress and development in accordance with the Charter of the United Nations.

Article II reaffirms the application of the Charter of the United Nations and of international law to outer space. While the Charter predates man's entry into space, its principles and provisions, including those relating to the permissible and impermissible uses of force, are as valid for outer space as they are for our seas, land, or air. The United States welcomes the international community's reaffirmation in the Moon Treaty of this essential point.

Article III contains a statement of the principle that the celestial bodies and those orbits around them and to them are only to be used for peaceful—i.e., non-aggressive—purposes.

Paragraph 2 of Article III spells out in some detail some of the consequences to be drawn from Article II. Specifically, paragraph 2's purpose is to make clear that it is forbidden for a party to the Moon Treaty to engage in any threat or use of force on the moon or in other circumstances set forth in paragraph 2 if such acts would constitute a violation of the party's international obligations in regard to the threat or use of force.

2. States Parties shall be guided by the principle of co-operation and mutual assistance in all their activities concerning the exploration and use of the moon. International co-operation in pursuance of this Agreement should be as wide as possible and may take place on a multilateral basis, on a bilateral basis, or through international intergovernmental organizations.

Article V

1. States Parties shall inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of their activities concerned with the exploration and use of the moon. Information on the time, purposes, locations, orbital parameters and duration shall be given in respect to each mission to the moon as soon as possible after launching, while information on the results of each mission, including scientific results, shall be furnished upon completion of each mission. In case of a mission lasting more than 60 days, information on conduct of the mission including any scientific results shall be given periodically at 30 days' intervals. For missions lasting more than six months, only significant additions to such information need be reported thereafter.

2. If a State Party becomes aware that another State Party plans to operate simultaneously in the same area of or in the same orbit around or trajectory to or around the moon, it shall promptly inform the other State of the timing of and plans for its own operations.

3. In carrying out activities under this Agreement, States Parties shall promptly inform the Secretary-General, as well as the public and the international scientific community, of any phenomena they discover in outer space, including the moon, which could endanger human life or health, as well as any indication of organic life.

Article VI

1. There shall be freedom of scientific investigation on the moon by all States Parties without discrimination of any kind, on the basis of equality and in accordance with international law.

2. In carrying out scientific investigations and in furtherance of the provisions of this Agreement, the States Parties shall have the right to collect on and remove from the moon samples of its mineral and other substances. Such samples shall remain at the disposal of those States Parties which caused them to

be collected and may be used by them for scientific purposes. States Parties shall have regard to the desirability of making a portion of such samples available to other interested States Parties and the international scientific community for scientific investigation. States Parties may in the course of scientific investigations also use mineral and other substances of the moon in quantities appropriate for the support of their missions.

3. States Parties agree on the desirability of exchanging scientific and other personnel on expeditions to or installations on the moon to the greatest extent feasible and practicable.

Article VII

1. In exploring and using the moon, States Parties shall take measures to prevent the disruption of the existing balance of its environment whether by introducing adverse changes in such environment, its harmful contamination through the introduction of extra-environmental matter or otherwise. States Parties shall also take measures to prevent harmfully affecting the environment of the earth through the introduction of extraterrestrial matter or otherwise.

2. States Parties shall inform the Secretary-General of the United Nations of the measures being adopted by them in accordance with paragraph 1 of this article and shall also to the maximum extent feasible notify him in advance of all placements by them of radioactive materials on the moon and of the purposes of such placements.

3. States Parties shall report to other States Parties and to the Secretary-General concerning areas of the moon having special scientific interest in order that, without prejudice to the rights of other States Parties, consideration may be given to the designation of such areas as international scientific preserves for which special protective arrangements are to be agreed in consultation with the competent organs of the United Nations.

Article VIII

1. States Parties may pursue their activities in the exploration and use of the moon anywhere on or below its surface, subject to the provisions of this Agreement.

2. For these purposes States Parties may, in particular:

(a) Land their space objects on the moon and launch them from the moon;

Article VII contains important protections for the environment of celestial bodies. The United States endorses the Committee's understanding that the language of this article is not intended to be read in such a way as would result in prohibiting the exploitation of natural resources to be found on celestial bodies but, rather, that any such exploitation is to be carried out in such a manner as to minimize, insofar as possible, disruption of or adverse changes in the environment.

(b) Place their personnel, space vehicles, equipment, facilities, stations and installations anywhere on or below the surface of the moon.

Personnel, space vehicles, equipment, facilities, stations and installations may move or be moved freely over or below the surface of the moon.

3. Activities of States Parties in accordance with paragraphs 1 and 2 of this article shall not interfere with the activities of other States Parties on the moon. Where such interference may occur, the States Parties concerned shall undertake consultations in accordance with article XV, paragraphs 2 and 3.

Article IX

1. States Parties may establish manned and unmanned stations on the moon. A State Party establishing a station shall use only that area which is required for the needs of the station and shall immediately inform the Secretary-General of the United Nations of the location and purposes of that station. Subsequently, at annual intervals that State shall likewise inform the Secretary-General whether the station continues in use and whether its purposes have changed.

2. Stations shall be installed in such a manner that they do not impede the free access to all areas of the moon of personnel, vehicles and equipment of other States Parties conducting activities on the moon in accordance with the provisions of this Agreement or of article I of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

Article X

1. States Parties shall adopt all practicable measures to safeguard the life and health of persons on the moon. For this purpose they shall regard any person on the moon as an astronaut within the meaning of article V of the Treaty on Principles Governing the Activities of States on the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies and as part of the personnel of a spacecraft within the meaning of the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

2. States Parties shall offer shelter in their stations, installations, vehicles and other facilities to persons in distress on the moon.

Article XI

1. The moon and its natural resources are the common heritage of mankind, which finds its expression in the provisions of this Agreement and in particular in paragraph 5 of this article.

2. The moon is not subject to national appropriation by any claim of sovereignty, by means of use or occupation, or by any other means.

3. Neither the surface nor the subsurface of the moon, nor any part thereof or natural resources in place, shall become property of any State, international intergovernmental or nongovernmental organization, national organization or nongovernmental entity or of any natural person. The placement of personnel, space vehicles, equipment, facilities, stations and installations on or below the surface of the moon, including structures connected with their surface or subsurface, shall not create a right of ownership over the surface or the subsurface of the moon or any areas thereof. The foregoing provisions are without prejudice to the international régime referred to in paragraph 5 of this article.

4. States Parties have the right to exploration and use of the moon without discrimination of any kind on a basis of equality, and in accordance with international law and the terms of this Agreement.

5. States Parties to this Agreement hereby undertake to establish an international régime, including appropriate procedures, to govern the exploitation of the natural resources of the moon as such exploitation is about to become feasible. This provision shall be implemented in accordance with article XVIII of this Agreement.

6. In order to facilitate the establishment of the international régime referred to in paragraph 5 of this article, States Parties shall inform the Secretary-

The common heritage concept, which was initially suggested by Argentina, but formally proposed by the United States in 1972, is set forth in Article XI, paragraph 1, which makes it clear that its meaning, for purposes of the Moon Treaty, is to be found within the Moon Treaty itself. Likewise, its meaning in the Moon Treaty is without prejudice to its use or meaning in any other treaty.

Article XI, paragraph 5, makes it clear that the parties to the treaty undertake, as the exploitation of the natural resources of the celestial bodies other than the earth is about to become feasible, to enter into negotiations to establish a mutually acceptable international régime to govern the exploitation of those mineral and other substantive resources which may be found on the surface or subsurface of a celestial body. Each of the participants in a régime conference will, of course, have to evaluate any treaty that emerges from the conference in the light of its own national interests. For the United States, this would require a conclusion that the treaty is balanced and reasonable and would then, as a constitutional matter, require submission to the Senate for its advice and consent, just as we have sought and obtained advice and consent to United States ratification of the four outer space treaties now in force.

General of the United Nations as well as the public and the international scientific community to the greatest extent feasible and practicable of any natural resources they may discover on the moon.

7. The main purposes of the international régime to be established shall include:

- (a) The orderly and safe development of the natural resources of the moon;
- (b) The rational management of those resources;
- (c) The expansion of opportunities in the use of those resources;
- (d) An equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the moon shall be given special consideration.

8. All the activities with respect to the natural resources of the moon shall be carried out in a manner compatible with the purposes specified in paragraph 7 of this article and the provisions of article VI, paragraph 2, of this Agreement.

The draft Moon Treaty, as part of the compromise by many delegations, places no moratorium upon the exploitation of the natural resources on celestial bodies by States or their nationals, but does provide that any exploitation of the natural resources of celestial bodies be carried out in a manner compatible with the purposes specified in paragraph 7 of Article XI and the provisions of paragraph 2 of Article VI. The United States views the purposes set forth in paragraph 7 as providing both a framework and an incentive for exploitation of the natural resources of celestial bodies. They constitute a framework because even exploitation which is undertaken by a State Party to the Treaty or its nationals outside of the context of any such régime either because the exploitation occurs before a régime is negotiated or because a particular State may not participate in the international régime once it is established, will have to be compatible with those purposes set forth in Article XI, paragraph 7, of the Moon Treaty.

This same paragraph is also an incentive. By setting forth now the purposes governing exploitation of natural resources, uncertainty is decreased and both States and private entities may now find it possible to engage in the arduous and expensive efforts necessary if exploitation of the natural resources of the celestial bodies is ever to become a reality. Especially vital in this regard is the fact that Article XI(7)(d) recognizes that an equitable sharing of the benefits derived from the natural resources of celestial bodies necessitates giving special consideration to those who have contributed directly to the exploration of the moon, as well as to the needs of developing countries and those who have indirectly contributed to the moon's exploration. This language also reflects the international cooperation that exists today in telecommunications and other practical applications of space—for example, Intelsat, Intersputnik and Inmarsat, where those States who have expended large resources, either public or private, to develop space systems to exploit these applications have equitably shared the benefits with the international community.

Article XI, paragraph 8, not only covers and sets the standards for the general right to exploit natural resources (in a manner compatible with Article XI(7)) but also is intended to ensure that the unrestricted right to collect samples of natural resources is not infringed upon and that there is no limit upon the rights of States Parties to utilize in the course of scientific in-

vestigations, such quantities of those natural resources found on celestial bodies as are appropriate for the support of their missions.

Article XII

1. States Parties shall retain jurisdiction and control over their personnel, vehicles, equipment, facilities, stations and installations on the moon. The ownership of space vehicles, equipment, facilities, stations and installations shall not be affected by their presence on the moon.

2. Vehicles, installations and equipment or their component parts found in places other than their intended location shall be dealt with in accordance with article V of the Agreement on Assistance to Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space.

3. In the event of an emergency involving a threat to human life, States Parties may use the equipment, vehicles, installations, facilities or supplies of other States Parties on the moon. Prompt notification of such use shall be made to the Secretary-General of the United Nations or State Party concerned.

Article XIII

A State Party which learns of the crash landing, forced landing or other unintended landing on the moon of a space object, or its component parts, that were not launched by it, shall promptly inform the launching State Party and the Secretary-General of the United Nations.

Article XIV

1. States Parties to this Agreement shall bear international responsibility for national activities on the moon whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Agreement. States Parties shall ensure that non-governmental entities under their jurisdiction shall engage in activities on the moon only under the authority and continuing supervision of the appropriate State Party.

2. States Parties recognize that detailed arrangements concerning liability for damage caused on the moon, in addition to the provisions of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies and the Convention

on International Liability for Damage Caused by Space Objects, may become necessary as a result of more extensive activities on the moon. Any such arrangements shall be elaborated in accordance with the procedure provided for in article XVIII of this Agreement.

Article XV

1. Each State Party may assure itself that the activities of other States Parties in the exploration and use of the moon are compatible with the provisions of this Agreement. To this end, all space vehicles, equipment, facilities, stations and installations on the moon shall be open to other States Parties. Such States Parties shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited. In pursuance of this article, any State Party may act on its own behalf or with the full or partial assistance of any other State Party or through appropriate international procedures within the framework of the United Nations and in accordance with the Charter.

2. A State Party which has reason to believe that another State Party is not fulfilling the obligations incumbent upon it pursuant to this Agreement or that another State Party is interfering with the rights which the former State has under this Agreement may request consultations with that Party. A State Party receiving such a request shall enter into such consultations without delay. Any other State Party which requests to do so shall be entitled to take part in the consultations. Each State Party participating in such consultations shall seek a mutually acceptable resolution of any controversy and shall bear in mind the rights and interests of all States Parties. The Secretary-General of the United Nations shall be informed of the results of the consultations and transmit the information received to all States Parties concerned.

3. If the consultations do not lead to a mutually acceptable settlement which has due regard for the rights and interests of all the States Parties, the parties concerned shall take all measures to settle the dispute by other peaceful means of their choice and appropriate to the circumstances and the nature of the dispute. If difficulties arise in connexion with the opening of consultations or if consultations do not lead to a mutually acceptable settlement, any States Party may seek the assistance of the Secretary-General without seeking the consent of any other State Party

concerned, in order to resolve the controversy. A State Party which does not maintain diplomatic relations with another State Party concerned shall participate in such consultations, at its choice, either itself or through another State Party or the Secretary-General, as intermediary.

Article XVI

With the exception of articles XVII to XXI, references in this Agreement to States shall be deemed to apply to any international intergovernmental organization which conducts space activities if the organization declares its acceptance of the rights and obligations provided for in this Agreement and if the majority of the States members of the organization are States Parties to this Agreement and to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies. States members of any such organization which are States Parties to this Agreement shall take all appropriate steps to ensure that the organization make a declaration in accordance with the foregoing.

Article XVII

Any State Party to this Agreement may propose amendments to the Agreement. Amendments shall enter into force for each State Party to the Agreement accepting the amendments upon their acceptance by a majority of the States Parties to the Agreement and thereafter for each remaining State Party to the Agreement on the date of acceptance by it.

Article XVIII

Ten years after the entry into force of this Agreement, the question of how the review of the Agreement shall be included in the provisional agenda of the United Nations General Assembly in order to consider, in the light of past application of the Agreement, whether it requires revision. However, at any time after the Agreement has been in office for five years, the Secretary-General of the United Nations, as depository, shall, at the request of one third of the States Parties to the Agreement and with the concurrence of the majority of the States Parties, convene a conference of the States Parties to review this Agreement. A review conference shall also consider the question of the implementation of the provisions of article XI, paragraph 5, on the basis of the principle referred to in paragraph 1 of that article and taking into account in particular any relevant technological developments.

Article XIX

1. This Agreement shall be open for signature by all States at United Nations Headquarters in New York.

2. This Agreement shall be subject to ratification by signatory States. Any State which does not sign this Agreement before its entry into force in accordance with paragraph 3 of this article may accede to it at any time. Instruments of ratification or accession shall be deposited with the Secretary-General of the United Nations.

3. This Agreement shall enter into force on the thirtieth day following the date of deposit of the fifth instrument of ratification.

4. For each State depositing its instrument of ratification or accession after the entry into force of this Agreement, it shall enter into force on the thirtieth day following the date of deposit of any such instrument.

5. The Secretary-General shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification or accession to this Agreement, the date of its entry into force and other notices.

Article XX

Any State Party to this Agreement may give notice of its withdrawal from the Agreement one year after its entry into force by written notification to the Secretary-General of the United Nations. Such withdrawal shall take effect one year from the date of receipt of this notification.

Article XXI

The original of this Agreement, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations, who shall send certified copies thereof to all signatory and acceding States.

IN WITNESS WHEREOF the undersigned, being duly authorized thereto by their respective Governments, have signed this Agreement, opened for signature at New York on