Aeronautics and Space Report of the President

1985 Activities

NOTE TO READERS: ALL PRINTED PAGES ARE INCLUDED, UNNUMBERED BLANK PAGES DURING SCANNING AND QUALITY CONTROL CHECK HAVE BEEN DELETED

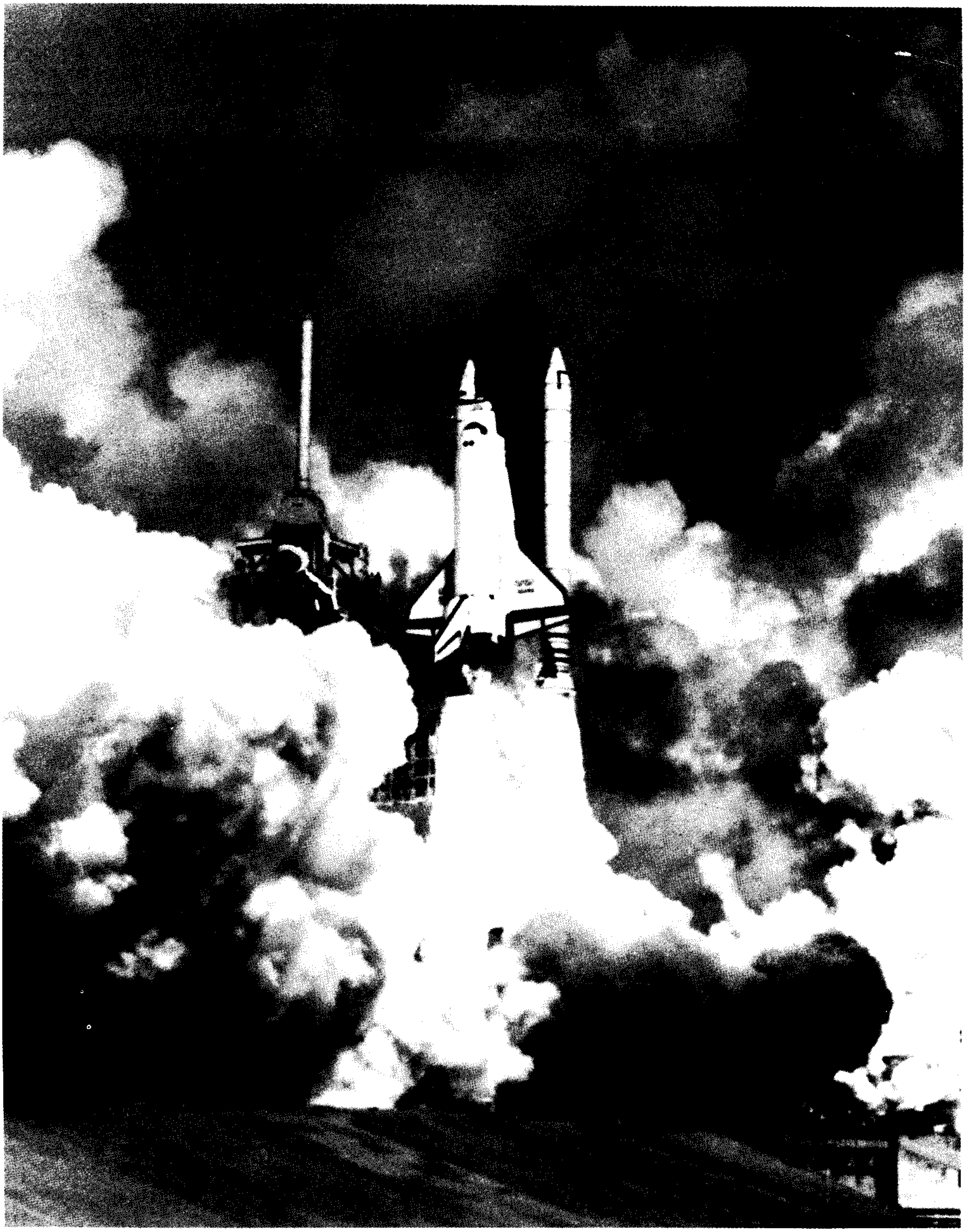
Aeronautics and Space Report of the President

1985 Activities

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

Contents

Appendixes



October 3, 1985, marked the maiden voyage of Atlantis, NASA's fourth and newest Orbiter.

Summary

Emerging from Discovery's cargo bay on June 19, 1985, the Telstar 3-D was one of 11 communications satellites that were boosted into orbit from Shuttle spacecraft.

During 1985, research activities in aeronautics and space, involving several federal agencies, continued to reflect the Nation's resolve to employ the aerospace environment for the benefit of humankind, to develop new areas of technology, and to expand understanding of forces that created the Earth, the solar system, the galaxies, and the universe.

The year's nine Space Shuttle missions focused heavily on the physical and life sciences, and included three Spacelab flights, one of which was managed by the government of West Germany. Six payload specialists represented foreign nations; a teacher was selected as the first private citizen to fly in space; and one mission included, as a payload specialist, Senator Jake Garn, who was subjected to extensive medical tests in weightlessness. One of two dedicated Department of Defense (DOD) missions marked the maiden voyage of the fourth Shuttle Orbiter, Atlantis. A total of 11 communications satellites were boosted into orbit from the Space Shuttle; two missions were involved in reactivation of the Syncom IV-3 satellite; and the last flight of the year demonstrated the ease with which astronauts can assemble large structures in space, a capability which has important implications for the future manned Space Station.

U.S. Senator Jake Garn conducts a medical experiment on himself during Space Shuttle mission 51-D.

During the first operational flight of Spacelab, the Spacelab 3 microgravity mission, large, well-defined crystals were grown, and life sciences experiments measured the effects of microgravity on animals. Other activities included fluid dynamics experiments, observations of the aurora, and atmospheric studies.

On the flight of Spacelab 2, several astronomy and astrophysics experiments were conducted. The European Space Agency's Instrument Pointing System was used for the first time and demonstrated its effectiveness as a stable platform for sensitive instruments.

In the area of solar system exploration, the encounter with Comet Giacobini-Zinner by the International Cometary Explorer provided the first spacecraft data on the composition of a comet. In

September, Voyager 2 obtained the first images of Uranus with sufficient resolution to improve our knowledge of that planet and its satellites.

Expendable launch vehicles continued to provide service for international communications networks. Three Atlas Centaur launches from the Eastern Space and Missile Center in Florida put the 10th, 11th, and 12th satellites of the INTELSAT V series into orbit. This increased to 14 the number of communications satellites available for the global service provided by the International Telecommunications Satellite Organization (INTELSAT). There were two Scout launches of DOD payloads from the Western Space and Missile Center, Vandenberg Air Force Base, California.

At White House request, the National Aeronautics and Space Administration (NASA) and DOD continued to examine technologies that would improve launch capabilities early in the next century. This included a study to define requirements for a second-generation Space Shuttle. For the near term, in support of the President's national policy for assured access to space, DOD will acquire 10 expendable launch vehicles to complement the Space Shuttle, and will refurbish a number of existing Titan II's to launch future national security payloads.

DOD and NASA combined efforts on a hypersonic cruise/transatmospheric vehicle research program. The concept for this program centers on the ability of aircraft to operate at hypersonic speeds in the upper atmosphere, and as a space launch vehicle capable of accelerating directly into orbit.

The U.S. Space Command, composed of Air Force, Navy, and Army elements, was established officially in Colorado Springs, Colorado. By centralizing responsibilities of the various service branches, this unified Command will allow more efficient pursuit of common space goals.

Pursuant to the Administration's declaration in 1984 that international communications satellite systems separate from INTELSAT were required in the national interest, the Federal Communications Commission (FCC) granted conditional authority to five companies to establish independent satellite systems. Also, in response to a petition filed by NASA, the FCC issued a Notice of Proposed Rulemaking to allocate spectrum positions for a mobile satellite system that would provide emergency communications and mobile telephone services in rural areas.

In accordance with the provisions of Public Law 98-365, authorizing the transfer of space-based land remote sensing to the private sector, the Government signed a contract with the Earth Observation Satellite Corporation (EOSAT) to manage and operate Landsat 4 and Landsat 5 and future Landsat 6 and Landsat 7 spacecraft. The Earth Resources Observation System (EROS) Data Center of the U.S. Geological Survey completed initial modifications to support the transition of Landsat to EOSAT. In 1985, EROS distributed approximately 46,000 film and digital products to users worldwide.

The commercial potential of space was demonstrated with the first sale of a product manufactured in microgravity. Tiny, perfectly formed polystyrene spheres, which had been produced during a Space Shuttle mission, were sold by the National Bureau of Standards for use as measurement reference materials by manufacturers of medicines, chemicals, and electronic components. In related activity, the Office of Commercial Space Transportation, Department of Transportation, issued its first major policy statement on commercial launch licensing procedures, and granted its first approval of a commercial launch.

In the international arena, the Department of State and other agencies worked closely with NASA on plans to develop the permanently manned Space Station, the largest international space project in history. Memoranda of Understanding on the design phase were signed with the European Space Agency, Japan, and Canada, and contracts for the definition and preliminary design phases were awarded to eight industry teams.

Several agencies were involved in the first session of the International Telecommunication Union's World Administrative Radio Conference held in Geneva, Switzerland, to review the system of allocating slots in geostationary orbit for communications satellites of various nations.

The Arms Control and Disarmament Agency prepared for a new series of bilateral arms control negotiations with the Soviet Union, the Nuclear and Space Talks.

The Voice of America covered all Space Shuttle launches, interviewed most of the astronauts, and distributed material about the U.S. space program to 134 nations and territories.

The remainder of this chapter is a summary by function of U.S. aeronautics and space activities in calendar year 1985. The succeeding chapters present activities of individual agencies in greater detail.

Communications

In order to maintain U.S. preeminence in the increasingly competitive communications satellite industry, NASA has been intensely involved in a program to develop advanced, proof-of-concept technology. Interest in experiments involving

NASA's Advanced Communications Technology Satellite continued. Several experiments using spot beams, hopping beams, and switchboard in-the-sky concepts will be conducted in the future.

NASA has developed technology that would provide a mobile telephone service in rural areas, for communications during medical emergencies and natural disasters, and for use in commerce by such organizations as trucking firms and oil and gas drilling enterprises. The FCC received a dozen applications from organizations proposing to build mobile satellite systems, and is in the process of allocating a domestic frequency for this service.

No longer responding to commands, NASA's ATS-1 (Advanced Technology Satellite), the backbone of southern Pacific island communications, was shut down. ATS-3 remains operational, continuing to support activities of several federal agencies, and was instrumental in relaying communications of relief organizations after the earthquake in Mexico and the volcanic eruption in Columbia.

Many developing nations perceive that future access to the geostationary orbit for their communications satellites will be limited due to monopolization of the orbit and its associated frequency bands by current users. The first of two sessions of the International Telecommunication Union's World Administrative Radio Conference on the Planning of the Geostationary Satellite Orbit and the Space Service Utilizing It was conducted for the purpose of reviewing procedures for allocating access to the orbit and spectrum.

The current era, characterized as the "Information Age," was made possible by communications electronics. Communications satellites now constitute a critical and fast-growing segment of the communications industry. Eleven communications satellites, representing eight organizations from five nations, were boosted into orbit from the Space Shuttle; and expendable launch vehicles launched three communications satellites into orbit for INTELSAT.

Recognizing the importance, for U.S. national interests, of technological advances in communications, computers, and information systems, the Department of State established a Bureau of International Communications and Information Policy.

Operational Space Systems

Search and Rescue. The COSPAS/SARSAT satellite system, to detect and relay transmissions of aircraft and ships in distress, began its first year of regular operations. The United States, Canada, France, and the Soviet Union developed the system; and Norway, the United Kingdom, Sweden, Finland, Bulgaria, Denmark, and Brazil also participate in its use. International participation has resulted in increased benefits and reduced costs for the combined satellite and ground system. By the end of 1985, use of the system in actual distress situations had saved 510 lives worldwide.

INTELSAT and INMARSAT. Service by the 109-member nation INTELSAT improved with launches of three satellites of the INTELSAT V series, making a total of 14 satellites available on a worldwide basis. The satellite constellation was reconfigured into operational zones providing six V's and one IVA in the Atlantic Ocean Region; three V's in the Indian Ocean Region; and two IVA's and two V's in the Pacific Ocean Region. Three of the IVA satellites exceeded estimated maneuver life. Approval was granted for 22 new Earth station facilities to access the INTELSAT system in the Atlantic Ocean Region for INTELSAT (digital) Business Service. Conditional authority was granted to five companies to establish international satellite communications systems separate from INTELSAT for business, video, and other private purposes.

In its fourth year of maritime communications service, the 44-member International Maritime Satellite Organization (INMARSAT) leased satellite capacity from U.S. satellite companies, the European Space Agency, and INTELSAT. Currently, INMARSAT leases three operational and three in-orbit spare satellites serving the Atlantic, Pacific, and Indian Ocean Regions. Second-generation satellites built to meet INMARSAT specifications, the first of which is expected to become operational in mid 1988, will have significantly increased capacity from that of the present leased spacecraft. INMARSAT serves about 4,000 vessels; and 13 coast stations in 10 nations are operational, with five more expected in 1986. At the fourth session of the INMARSAT assembly, amendments to the INMARSAT convention were adopted, along with an operating agreement that allows INMARSAT to provide aeronautical communications services. The assembly also adopted an international agreement on the use of INMARSAT ship-Earth stations within territorial seas and ports.

National and international efforts to establish a future global maritime distress and safety system are continuing. The system under development will use terrestrial techniques and satellite emergency position indicating radio beacons (EPIRB's) to relay information from ships to rescue coordination centers. Current plans call for satellite EPIRB's to operate through INMARSAT and COSPAS/SARSAT, and a decision on future operations will be made in 1986.

Domestic Communications Satellites. Currently, there are 25 domestic communications satellites in service. The FCC authorized the construction and launch of 20 additional domestic fixed-satellites that will provide communication services through the end of the century. Several licenses were awarded to companies new to the satellite industry under this authorization. In order to reduce orbital spacings, locations for new satellites in the geostationary orbit were assigned with 2-degree separations in both the 4/6-GHz and 12/14-GHz bands. The FCC's Advisory Committee on 2° Spacing was established to elicit recommendations by industry on the most efficient and economical methods to accommodate satellite operations under the conditions of reduced spacing. Conditional construction permits for new Direct Broadcast Satellite (DBS) systems were issued to three "third-round" applicants. After fulfilling the "due diligence" requirement, they will be eligible for assignment to specific orbital positions and channels. Three of the eight "first-round" DBS companies are continuing to construct their satellites; one of the six "second-round" DBS companies has demonstrated "due diligence"; and, currently, a "fourth-round" of DBS applicants is pending. New technology continued to bring improved satellite service to users. The FCC allocated frequencies for domestic radio determination satellite service that will allow subscribers to determine latitude, longitude, and altitude, and to exchange messages using hand-held transceivers.

Military Communications Satellites. Military Satellite Communications (MILSATCOM) is a system that provides a reliable and survivable linkage between decision makers and military forces deployed worldwide. A crucial part of the President's strategic modernization program is Milstar, a communications satellite system that will provide jam-resistant, survivable voice communications for national command authorities. The Air Force is responsible for airborne and some strategic ground terminals, and the Navy and Army for shipboard and ground terminals, respectively. Plans for the satellite control segment were developed by the Air Force; an engineering development contract was awarded for the Army's terminals; and the Navy demonstrated two prototype terminal designs.

Navigation Satellites. Navstar II, the last developmental Global Positioning System (GSP) satellite, was launched, bringing to seven the number of GPS developmental satellites, all of which are performing well. These satellites provide radio position and navigation information to support defense missions worldwide.

Earth's Atmosphere, Environment, and Resources

Sophisticated equipment on aircraft, marine vessels and spacecraft continue to help increase understanding of the processes, composition, and origin of the Earth's atmosphere, environment, and natural resources.

Monitoring and Analysis

Satellite Operations. The Nation's primary operational polar weather satellites, NOAA 8 and 9, orbit the Earth about the poles in Sunsynchronous orbits and provide environmental observations of the entire Earth four times each day. NOAA 9 is the first operational spacecraft to carry solar backscatter ultraviolet radiometers that provide, for both NASA and NOAA, global measurements of atmospheric ozone concentration. It also carries the Earth Radiation Budget Experiment (ERBE) that measures the Earth's radiation balance between incoming and outgoing energy, and supplies data for NASA's continuing climate research activities. ERBE received and processed data both from the instruments aboard the NOAA 9 spacecraft and from the Earth Radiation Budget Satellite, boosted into orbit from the Shuttle in 1984. Among interesting scientific data that have emerged are measurements of the "solar constant," or solar irradiance at the mean distance of the Earth from the Sun.

NOAA's GOES 6 (Geostationary Operational Environmental Satellite) continued to provide valuable imaging and sounding data about the summer/fall hurricane season and winter weather conditions. Coverage by the VAS (VISSR Atmospheric Sounder) on GOES was modified to support operations at the National Hurricane Center. Throughout the hurricane season, VAS data were used to monitor the development, strength, and movement of tropical storms in the Gulf of Mexico, the Atlantic Ocean, and the Caribbean Sea. The GOES data Collection System relays environmental data from remotely located Data Collection Platforms to 68 national and 28 international users. A contractor was selected to build the "GOES-Next" series (GOES I-M) planned for operation in the 1990's.

The International Satellite Cloud Climatology Project (ISCCP), co-sponsored by the World Meteorological Organization and the International Council of Scientific Unions, entered its second year of collecting and processing data on the global distribution of clouds supplied by an international array of polar orbiting and geostationary satellites. NASA continues to play an important role in the ISCCP through its support of the Global Processing Center, where data are merged and analyzed. The national project office for the First ISCCP Regional Experiment, established by NASA, issued an implementation plan that focuses on modeling activities and data gathering on cirrus and marine stratocumulus cloud systems, both believed to be important to the Earth's radiation budget and climate. With support from several federal agencies, the plan will be implemented by a university/government science team.

Atmospheric, Oceanic, and Geologic Research. Joint efforts of NASA, the Federal Aviation Administration, the National Oceanic and Atmospheric Administration, the World Meteorological Organization, the U.N. Environmental Program, and the Federal Republic of Germany culminated in a report assessing perturbations in the distribution of ozone in the atmosphere and adjacent regions.

NASA and the government of Brazil conducted a joint atmospheric chemistry and meteorology experiment in the Amazon rain forest. The purpose was to test hypotheses about the unusual distributions of carbon monoxide off South American coasts that were detected by a sensor aboard a Space Shuttle flight.

In oceanography, NASA is developing the Scatterometer (NSCAT) to fly aboard the Navy's Remote Ocean Sensing System satellite. NASA is also studying the possibility of initiating the Ocean Topography Experiment (TOPEX), a dedicated altimetric satellite, and the Ocean Color Imager (OCI), an improved version of the Coastal Zone Color Scanner currently flying aboard Nimbus-7. TOPEX, NSCAT, and OCI are key elements of the World Climate Research Program, and, if developed, will improve capabilities for understanding how atmospheric and oceanic forces influence the Earth's climate.

The Navy's geodetic and geophysical satellite (GEOSAT) was boosted into orbit. Its mission is to determine a global marine geoid by measuring small variations in the height of the ocean surface. The satellite will also furnish useful oceanographic information about surface wind speeds, and the location of ocean fronts and eddies.

The Federal Aviation Administration conducted technical and operational investigations using a Doppler weather-radar support facility to detect low-altitude wind shear and other conditions. Installation of Low Level Wind Shear Alert Systems in the Nation's airports continued, along with tests using additional periphery sensors to detect wind shears generated by microbursts. Under NASA's Mesoscale Atmospheric Research Program, new techniques are being developed to use remote sensing to identify deadly microbursts and tropical cyclones, and to make calculations that will lead to more precise storm warnings.

As the transfer of the Landsat system to the private sector was taking place, NASA completed a 2-year study of the Thematic Mapper carried on Landsat, and initiated a new science investigations program using the sensor. The new science program complements the previous program that focused on nearer term applications, and is aimed at developing next generation systems for scientific and commercial use beginning in the mid-1990's. The U.S. Geological Survey conducted two international remote sensing workshops on topics such as the application of Landsat data to geologic and hydrologic assessment problems, and the application of digital image processing techniques to resource monitoring and mapping.

A significant milestone was reached with the conclusion of the Department of Agriculture's AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing). This was a 6-year, multi-agency, cooperative effort to determine the feasibility of integrating remote sensing technology into the Department of Agriculture's information system for such purposes as forecasting crop production, assessing renewable resources, and detecting pollution. The Department's Agricultural Research Service established a Remote Sensing Research Laboratory under a newly created Agricultural Systems Research Institute. The Laboratory is expected to play a major role in developing useful applications of remote sensing data.

NASA initiated the Interdisciplinary Research Program to investigate long-term physical, chemical, and biological changes in the Earth's environment. The agency's Geodynamics Program obtained measurements of the movement of tectonic plates that make up the crust of the Earth. Measurements using special spacecraft, such as the Laser Geodynamics Satellite and Very Long Baseline Microwave Interferometry, should lead to a better understanding of the causes of motions and the geophysics of crustal deformation in earthquake prone areas. NASA and other agencies are in the process of developing the use of DOD Global Positioning Satellites for geodetic measurement.

The Environmental Protection Agency and NASA are cooperating in the development and application of a number of aerospace technologies to monitor and assess the environment. This includes the creation and use of a computerized Geographic Information System as a data base and an inventory of such environmental variables as weather conditions, land uses and soil types, and water well locations.

Space Science

Space science programs investigate the origin and evolution of life, the Earth, the solar system, and the universe. Investigations are aided by satellites, space probes, experiments conducted on the Space Shuttle, suborbital vehicles, and ground-based facilities. In 1985, the microgravity of space proved to be an ideal environment for conducting research in the medical and biological sciences.

Solar System Exploration

Cometary Studies. The encounter of the International Cometary Explorer (ICE) with Comet Giacobini-Zinner provided valuable information on a comet's magnetic field, plasma environment, and dust content. ICE, along with the Pioneer Venus spacecraft, also are scheduled to observe the more famous Comet Halley during its approach to the Sun between February and April 1986.

Voyagers 1 and 2. Voyager 2 obtained images of Uranus, its satellites, and its rings, the first such pictures ever made by a spacecraft. New tracking, communications, and operating procedures were established for data collection in preparation for Voyager's close encounter with Uranus in 1986. When Voyager 2 leaves Uranus, it will travel on a trajectory toward Neptune, which it is expected to reach in 1989. Voyager 1, on a path toward the star Rasalhagne, about 25 astronomical units from the Sun, has ventured farther above the ecliptic plane of the solar system than any previous spacecraft.

Pioneer Venus. Instruments on the Pioneer Venus Orbiter spacecraft, in its sixth year of operation, made significant new measurements of the solar wind's interaction with Venus. Aurorae, called "Northern Lights," were also discovered in the atmosphere of Venus. The observation of Comet Giacobini-Zinner by Pioneer's Ultraviolet Spectrometer during ICE's encounter with that Comet resulted in a better understanding of the Comet's rate of water evaporation.

Pioneers 10 and 11. Pioneer 10, now about 37 astronomical units from the Sun, continues to return data about the solar system, aiming to detect the heliopause, the boundary between the Sun's magnetic influence and interstellar space. Pioneer 11, traveling in the opposite direction from Pioneer 10, is now past the orbit of Uranus, about 20 astronomical units from the Sun.

Galileo and Ulysses. Flight software was tested on Galileo, a spacecraft that will be launched on a mission to study Jupiter and its moons. Pre-launch testing of the Ulysses spacecraft, a joint effort with the European Space Agency, was also conducted. Ulysses will circle Jupiter, and then traverse the Sun's south pole.

Venus Radar Mapper and Mars Observer. Critical reviews were completed of the Venus Radar Mapper, which will use orbital radar to map the cloud-shrouded surface of Venus. Proposals were solicited and received for both the Mars Observer spacecraft and the scientific investigations that it will carry when it orbits Mars on a future mission to study that planet's surface and climate.

Space Plasma Physics. The National Academy of Sciences completed a study entitled "An Implementation Plan for Priorities in Solar-System Space Physics" which proposes a 10-year plan of solar and space plasma physics research. The International Solar-Terrestrial Physics program is given the highest priority, with the United States contributing to mission support in the form of satellites, instruments, data handling and modeling. The Dynamics Explorer 2 (DE-2) re-entered the atmosphere after providing considerable information about solar interactions with the Earth's atmosphere and magnetic field; another spacecraft, DE-1, continues to provide new data on the interactions between hot magnetospheric plasma and cool ionospheric plasma, and on auroral morphology. A total of 22 space plasma physics sounding rockets were launched to study properties of the middle atmosphere and the auroral regions. Important data were obtained on plasma flow, plasma turbulence, electric fields, and coupling from the polar ionosphere to the middle atmosphere.

Study of the Universe

NASA's Astrophysics program investigates the physical nature of the universe, from the star nearest the Earth, the Sun, to the most distant quasars. Since many observations cannot be made through the Earth's atmosphere, instruments for such observations must be carried above the atmosphere into space.

High Energy Astronomy Observatories (HEAO). Data from HEAO-2 revealed the existence of a significant amount of "dark matter" in galaxies and x-ray "haloes" surrounding the optical disks of galaxies. A determination of the origin of these phenomena is expected when a future x-ray facility is launched and operational. Five scientific instrument proposals for such a facility were selected for definition.

Gamma Ray Observatory (GRO). Design and the critical design review of GRO, which will investigate the highest energy reaches of the electromagnetic spectrum, were completed, along with testing and assembly of all hardware for the four GRO scientific instruments.

Solar Maximum Mission (SMM). The SMM, repaired in orbit by the crew of the Space Shuttle in 1984, provided valuable new information about solar flares, solar eruptions, and the global solar corona. Possible use of a reconfigured SMM that could accommodate future scientific payloads such as the Extreme Ultraviolet Explorer is being explored.

Hubble Space Telescope. Launch readiness for the Hubble Space Telescope is nearing. This astronomical observatory will be able to detect and observe celestial objects with considerably more precision than is currently possible.

Astro. The Astro payload, three complementary ultraviolet telescopes that will photograph and measure a variety of celestial objects, has been fully integrated into the European Space Agency's Instrument Pointing System and will be carried on Spacelab.

Spartan. The first Spartan mission was conducted when the small, versatile spacecraft was deployed from the Space Shuttle to map the central region of the Milky Way and the Perseus cluster of galaxies.

Life Sciences

In preparation for the permanent presence of humans in space, an important objective of NASA's Life Sciences program is to determine the effects of long-term space flight exposure on humans.

Space Medicine. Emphasis was placed on monitoring and maintaining the health of crews experiencing weightlessness during Space Shuttle missions. Diagnostic techniques for assessing bone demineralization and muscle atrophy were tested; experiments were conducted on the effectiveness of space motion sickness treatments and the ability of the gastrointestinal tract to absorb drugs; and dosimeters were used to monitor crew member radiation exposures and background radiation penetrating the Space Shuttle cabin.

Gravitational and Planetary Biology. The Gravitational Biology program endeavors to understand how gravity has shaped life on Earth, and to determine how microgravity affects both plants and animals. Results of ground-based animal studies were confirmed during the data analysis of Spacelab 3, which carried 12 adult and 12 juvenile rats. Substantial progress was also made in understanding the gravity-sensing mechanisms of plants. These studies have important implications for future manned space flight, and for biological life support systems that will provide food, water, and oxygen for crews.

The Planetary Biology program investigates conditions and processes required for the origin and evolution of life. In 1985, scientists speculated that certain clay minerals were important factors in the origin of life and may have significantly influenced the rate and direction of chemical evolution.

Controlled Ecological Life Support System. This program develops technology for life support systems that regenerate air, water, and food needed for long duration manned missions. Research focused on techniques for growing higher plants and algae in space, and recycling solid and liquid wastes.

Spacelab

The launch of Spacelab 2 culminated nearly 10 years of work. Flight verification tests of Spacelab's igloo-pallet configuration were conducted, and the Instrument Pointing System was used. Important data were obtained in solar and plasma physics, x-ray and infrared astronomy, cosmic ray astronomy, life sciences, and technology. Spacelab 3 was a 7-day microgravity mission that yielded exciting results in materials science, life sciences, fluid mechanics, and atmospheric and astronomical observations.

Microgravity Science

Scientific experiments involving semi-conductor materials, miscibility gap materials, and containerless processing of glass melts were conducted on the second flight of the Materials Experiment Assembly, which flew as part of the German D-1 Spacelab mission.

The Microgravity Materials Science Laboratory was opened at NASA's Lewis Research Center for the purpose of assisting industry, academia, and government researchers requiring special equipment and new processes to conduct future experiments in microgravity.

Space Transportation

NASA's Space Flight program experienced its busiest year ever with nine flights of the Space Shuttle. A public official was flown aboard the spacecraft for the first time; eleven communications satellites were boosted into orbit from the Space Shuttle; and three Space Shuttle missions used Spacelab. Three Atlas Centaur and two Scout expendable launch vehicles placed military and civilian satellites into orbit.

Shuttle Operations and Missions

To improve Mission Control operations at Johnson Space Center, a procurement contract was under negotiation to replace overloaded and outdated computers. The Center awarded a Space

Transportation System operations contract that consolidated support contracts involving several firms.

Orbiter improvement programs continued that will significantly improve performance on future flights. Work centered on the auxiliary power unit, brakes, nosewheel steering, general purpose computer, and inertial measurement unit. Flight certification extension testing of the Space Shuttle main engines (SSME's) at 104-percent power level was completed, along with the Phase II certification test program involving SSME high pressure pumps.

All Space Shuttle external tanks that were flown performed as expected. Ten tanks were manufactured and delivered on or ahead of schedule and, at the end of the year, fifteen tanks were in various stages of manufacture at the Michoud Assembly Facility in Louisiana.

The Space Shuttle's Solid Rocket Boosters (SRB's) continued to perform as predicted; all were recovered and are being refurbished. Development of the Filament Wound Case (FWC) for the SRB continued with completion of two static test firings. The composite cases for the first flight from Vandenberg Air Force Base were delivered, and stacking of the first FWC SRB began.

In accordance with the Shuttle's commitment to national security requirements, the first Shuttle flight of the year was also the first dedicated DOD Shuttle mission. The second dedicated DOD mission was also the maiden voyage of Atlantis, the fourth Shuttle orbiter.

When astronauts ventured outside the confines of the Space Shuttle on three separate missions to perform extravehicular activity (EVA), they proved once again that one of the most important assets of the spacecraft is its crew. The first mission EVA made preparations for the second mission spacewalk which enabled successful activation of the Syncom IV-3 communications satellite. The third mission EVA involved assembling and disassembling structures in space, activities that are crucial to the success of building the Space Station.

Payloads. The missions of Spacelab 3, Spacelab 2, and the West German D-1 Spacelab mission were highly successful, providing valuable new information on space science to the U.S. and international scientific communities. Spacelab 3 flew the first large-scale animal colony, and several experiments were conducted in the areas of life sciences, microgravity processes, and atmospheric observation. Spacelab 2 carried the Instrument Pointing System, used as a stable platform for astronomical instruments; and investigations were conducted in various scientific disciplines. The West German D-1 Spacelab mission introduced a new feature of reimbursable Shuttle flights – the scientific laboratory for hire. Its crew included one Dutch and two German payloads specialists who performed experiments, assisted by NASA's mission specialists.

A total of 52 individuals flew aboard Shuttle spacecraft. This group included payload specialists from five foreign countries, and U.S. Senator, Jake Garn, who flew as an observer. NASA also selected teacher, Christa McAuliffe, to fly in space as part of the citizen participation program. In preparation for a January 1986 launch of the Space Shuttle, she spent the last four months of 1985 in training, along with her backup, Barbara Morgan.

The eleventh class of astronaut candidates was selected, which includes six pilots and seven mission specialists. Henceforth, NASA will accept applications and maintain a roster of eligibles from which selections will be made as needs arise.

Upper Stages. A major effort in upper stages was the continued design, development, and procurement of the STS/Centaur. Two versions are under development: the Centaur G prime, for use in NASA's Galileo and Ulysses missions, and the Centaur G, funded jointly by NASA and DOD.

Commercially developed upper stages such as the PAM-D and the PAM-DII also play a major role in the Nation's space activities. They performed well on several missions launched by expendable launch vehicles and the Shuttle. Other upper stages with increased capabilities to lift payloads into orbit, such as the Transfer Orbit Stage and the Apogee Maneuvering Stage, are under development.

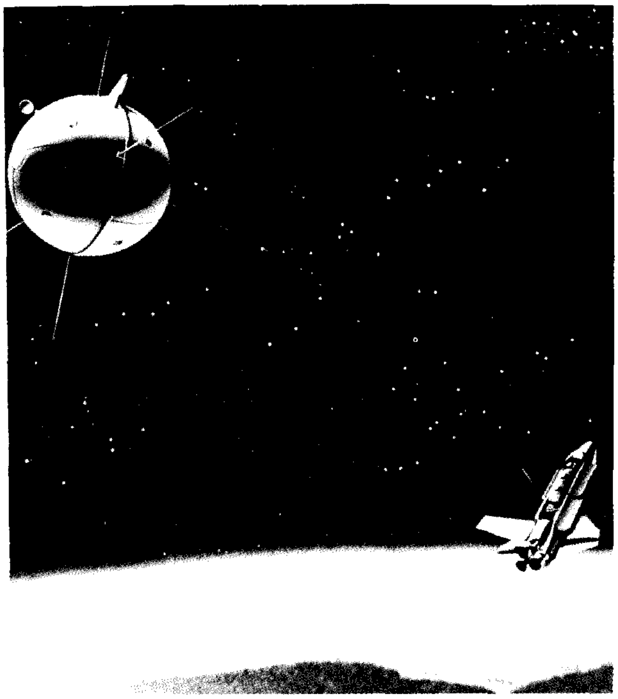
Tethered Satellite System

Science investigations for the first mission were selected and preliminary design reviews were conducted on the Tethered Satellite System, a cooperative development between NASA and Italy. The system will provide the capability to conduct experiments in the upper atmosphere and ionosphere by means of a tethered satellite that can be deployed and retrieved up to 100 kilometers below or above the Space Shuttle.

Advanced Planning

System definition studies were completed for an Orbital Maneuvering Vehicle capable of performing payload delivery and retrieval from the Space Shuttle. Initial studies also were completed of an Orbital Transfer Vehicle, a high-performance upper stage that will be based at and launched from the Space Station.

In accordance with a White House directive to define technologies that will improve launch



Artist's depiction of the Tethered Satellite System.

capabilities in the 1990's and beyond, NASA and DOD are currently examining concepts for future launch vehicles.

Commercial Use of Space

The Office of Commercial Space Transportation of the Department of Transportation is responsible for encouraging, regulating, and promoting a commercial expendable launch vehicle industry. In 1985, the Office reviewed policies affecting the commercial space industry, and established an interagency working group of representatives from the Departments of State, Defense, and Commerce, the National Aeronautics and Space Administration, and the Federal Communications Commission to coordinate and expedite review of launch proposals, license applications, and regulatory issuances. The Department's Commercial Space Transportation Advisory Committee met twice to discuss such issues as financing and insurance for commercial space ventures, licensing procedures, use of national launch ranges, and maintaining the confidentiality of proprietary data.

NASA's Office of Commercial Programs, established to encourage investment in commercial space ventures and to facilitate the application and transfer of existing aeronautics and space technology to the private sector, has completed its first full year of operation. Five Centers for the Commercial Development of Space were selected and funded for the purpose of conducting space research in areas considered to have commercial potential. The Modified Launch Services Agreement, a new type of agreement for doing business with the private sector, was developed; and significant progress was made in information and technology dissemination through wider circulation of the publication, *NASA Tech Briefs*, and through the establishment of additional independent university and state-sponsored Industrial Applications Centers.

Space Tracking and Data Systems

NASA's space tracking and data systems program continued to provide vital tracking, command, telemetry, and data acquisition support to meet the requirements for NASA, other U.S., and international programs. Once the required satellite constellation of three Tracking and Data Relay Satellites are in orbit, the program will reduce substantially the ground-based tracking network that supports low-Earth orbit spacecraft. The first Tracking and Data Relay Satellite, launched in 1983, provides excellent support of the Space Shuttle, Landsat, the Earth Radiation Budget Satellite, the Solar Mesospheric Explorer, and the Solar Maximum Mission.

The Ground Network, composed of the Spaceflight Tracking and Data Network, the Deep Space Network, and facilities that support aeronautics, balloon, and sounding rocket programs, provided support for several missions. The Deep Space Network supplied vital tracking and telemetry support for the Soviet-French balloons inflated in the atmosphere of Venus, and for the International Cometary Explorer's encounter with Comet Giacobini-Zinner. A major improvement of the Deep Space Network that will increase its ability to acquire scientific data also was completed. For the near term, this improvement will allow acquisition of more images from Voyager as it travels closer to the planet Uranus in 1986.

Space Station

NASA's Space Station program moved closer to the realization of President Reagan's goals to develop a permanently manned Space Station, with international participation, and to promote private sector investment in space.

In cooperation with NASA's Office of Aeronautics and Space Technology, an extensive advanced development program was initiated. A series of technology test-beds were established at various field centers that will validate the performance of components and subsystems during advanced development. Evaluation and testing also were initiated in major disciplines such as attitude control and stabilization, environmental control and life support, and auxiliary propulsion.

Contracts were awarded for each of four work packages designated for the definition and preliminary design phase of the Space Station; a Space Station system engineering and integration program office was established at Johnson Space Center; an operations concept for the Space Station was formulated; a key engineering report on the subjects of automation and robotics and a plan to implement the report's recommendations were submitted to Congress; and agreements were formalized through Memoranda of Understanding with Canada, Japan, and the European Space Agency on the definition and preliminary design phase of the program.

Aeronautics and Space Research and Technology

U.S. efforts in aeronautics research and technology continue to improve capabilities in civil and military aviation, and to expand the industrial base, contributing significantly to economic self-sufficiency and national security. These efforts span the flight spectrum from hovering to hypersonic aircraft. Wind tunnels, supercomputers, simulators, and experimental flight vehicles are examples of some of the research tools used to meet today's design challenges and to help fashion tomorrow's aircraft.

In the areas of space exploration and space science, U.S. advances are made in conjunction with developments in space research and technology programs. NASA's centers work with industry, and universities to increase the capabilities of space transportation systems; to develop large space systems and structures such as the Space Station and geosynchronous communications platforms; and to plan, design, and develop manned planetary missions, lunar bases, and spacecraft for Earth observation and planetary exploration.

Aeronautics

To insure continued U.S. leadership into the next century, the White House Office of Science and Technology Policy issued a report recommending specific goals for aeronautical research and development. For U.S. aeronautics programs, these goals present substantial challenges which translate into exciting opportunities for both the public and the private sectors.

Joint Programs. NASA/DOD research programs such as those for the X-29A forward-swept wing aircraft, the tilt rotor/JVX aircraft, the oblique wing research aircraft, and the convertible gas turbine engine allow the United States to maintain its superiority in the areas of civil and military aviation. In the area of aviation safety, joint NASA/FAA programs investigate such conditions as aircraft icing, wind shear, lightning strikes, and circumstances under which crew errors occur.

In 1985, the flight research program of the X-29A began. The unique forward-swept wing of the aircraft is made of composite materials that reduce the wing's weight up to 20 percent compared to the weight of conventional aft-swept wings. The forward "canard" wings are computer adjusted 40 times a second to improve flight efficiency and aircraft agility.

The new and revolutionary convertible gas turbine engine was demonstrated at NASA's Lewis Research Center. It allows a gas turbine engine's output to be in the form of either shaft power or fan power. This type of propulsion system is required for advanced high-speed rotorcraft concepts such as the X-wing, where rotor blades operating in a spinning mode for takeoff and landing are stopped and locked in place as an X-shaped fixed wing for high-speed flight.

Flight testing began in the Mission Adaptive Wing program using an F-111 aircraft to demonstrate use of variable smooth camber (fore to aft curvature) wing technology. The wing can change its contour in flight by means of a computerized system of sensors, controls, and internal hydraulic actuators, a capability which significantly increases aircraft range, maneuverability, and fuel efficiency.

A joint NASA/Canada program to test a large-scale short takeoff and vertical landing (STOVL) flight model was initiated. A cooperative program with the United Kingdom to investigate advanced STOVL concepts is planned.

NASA's Lewis Research Center conducted a symposium for industry that focused on an Electro-Impulse Deicing System that shows potential as an effective, lightweight ice protection system with many aeronautical uses.

Fluid and Thermal Physics. Computational Fluid Dynamics (CFD) has become important for understanding aircraft and propulsion system flow physics. The Numerical Aerodynamic Simulation System under development at NASA's Ames Research Center will provide the most advanced computational methods in the world for solutions to CFD problems. The system's Cray 2 supercomputer, currently the most powerful and fastest in the world, was delivered and installed.

Materials and Structures. NASA has conducted substantial research on structures composed of composite materials that are lighter and stronger than metals. An Air Force KC-10 aircraft was flown with a NASA-developed vertical stabilizer fabricated with graphite/epoxy composites. Advanced technologies for lightweight structures are important for development of supersonic aircraft.

Research in Wind Tunnels. The National Transonic Facility became fully operational at NASA's Langley Research Center. It is a unique wind tunnel that uses a cryogenic test gas and is capable of simulating and controlling actual flight parameters for advanced aerodynamics research.

Tests were conducted on single-rotation and counter-rotation propfan models in wind tunnels at NASA's Lewis and Langley Research Centers to determine high-speed performance, flutter, and acoustic characteristics. Advanced propellers or propfans can provide jetliner speeds at fuel consumption rates 20 to 30 percent lower than those of jet engines.

Propulsion. Current research on propulsion involves a variety of technologies that promise more effective research tools, engine components, and system capabilities.

Space

Space research and technology programs provide critical elements of the technology base that allow the United States to maintain its leadership in space activities. The programs involve the disciplinary areas of propulsion, space energy, aerothermodynamics, materials and structures, controls, automation and robotics, human factors, computer sciences and sensors, data and communications systems, and in-space experiments.

Propulsion. Thermal models designed to calculate the temperatures of cryogenic bearing elements under variable operating speeds, loads, and coolant flow rates were developed and are being validated in a NASA test facility that simulates actual loads occurring in high-pressure cryogenic turbopumps. An isotope bearing-wear detector and a fiber-optic deflectometer also were tested in this facility. These diagnostic sensors will be integrated into Space Shuttle Main Engine turbopumps for evaluation during actual engine operations.

Space Energy. The thermoelectric reactor power system concept was selected by NASA, the Department of Defense, and the Department of Energy for further design, development, and ground demonstration testing in Phase II of the SP-100 Space Reactor Power Program.

Changes in the chemistry and design of nickel-hydrogen batteries resulted in a 6-fold increase in cycle life and show promise of meeting the 50,000 cycle requirement of low-Earth orbit systems. As a result of this advance, nickel-hydrogen batteries are now a prime candidate for energy storage on the Space Station and associated scientific platforms.

Aerothermodynamics. Progress continues to be made in developing advanced computational methods to characterize the complex flowfields of aeroassisted orbital transfer vehicles. The main concern for these vehicles is the effect of flow they encounter maneuvering in the Earth's upper atmosphere. A computational code, based on a full Navier-Stokes solution to the aerobrake flowfield problem, was developed and permitted detailed study of proposed aerobrake designs.

Significant changes were made to the Columbia orbiter to accommodate three research experiments to measure orbiter aerodynamic and thermodynamic characteristics as the spacecraft reenters the Earth's atmosphere. Data from these experiments will contribute significantly to validation of the aerothermodynamic data base, and will assist in the design and development of future space transportation systems.

Materials and Structures. Silica and silicon carbide (Nicalon) fibers were woven into 3-dimensional fabrics for the first time, for use in the high-performance thermal protection system (TPS) required by the Orbital Transfer and advanced Earth-to-Orbit vehicles. This innovative technology will provide lightweight, high strength, reusable TPS structural concepts.

The first demonstration of in-space construction and repair techniques was the Experimental Assembly of Structures in Extravehicular Activity/Assembly Concept for Construction of Erectable Space Structures (EASE/ACCESS), conducted by crew members of Shuttle mission 61-B. Data from the flight will be used in developing methods for future space construction.

Human Factors. Because existing astronaut space suits will be inadequate for future Space Station extravehicular activity, a new suit was designed and tested at NASA's Ames Research Center. A helmet-mounted device to improve visual monitoring of remote operations in space also was designed.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration (NASA), established in 1958, is responsible for planning, conducting, and managing civilian research and development activities in aeronautics and space. The Department of Defense (DOD) is responsible for the Nation's military aeronautics and space programs. Although the missions are different, there is extensive cooperation between NASA and DOD. Other federal agencies, state, local, and foreign governments, as well as educational institutions and private industry, also share in NASA's programs.

NASA's mission continues to reflect the intent of Congress in creating the agency; that is, to explore space for peaceful purposes, with international cooperation, for the benefit of all humankind. Technological advances have resulted in significant economic and social benefits for the United States and other nations, and remain the catalyst for national pride, progress and achievement. The continued success of NASA's programs will allow the U.S. to maintain its leadership status in aeronautics and space.

Space Science and Applications

During 1985, NASA's scientific research continued to focus on the origin, evolution and structure of the universe and on the fundamental laws of physics that govern it. This research involves observation of the distant universe, exploration of the near universe, and characterization of Earth and its environment. Space science efforts include astrophysics, astronomy, planetary exploration and life sciences. Applications efforts include Earth science and applications, materials processing, communications, and information systems.

Applications

Communications

In 1973, NASA launched its last experimental communication satellite, and, for a few years, remained only minimally involved in this area of advanced technology. However, concerns arose about possible congestion of the frequency spectrum and the geostationary orbital arc, and about competition with Europe and Japan in satellite communication technology. In 1978, in cooperation with U.S. industry, NASA initiated a vigorous program to develop advanced high-risk, proof-of-concept technology which would be available to U.S. spacecraft manufacturers to ensure continued growth of this important industry, and to maintain U.S. preeminence in the world marketplace.

Advanced Communications Technology Satellite (ACTS). In 1984, NASA was directed by Congress to start work on ACTS, the world's most advanced communication technology satellite. ACTS will be built by expanding upon proof-of-concept technology developed for ACTS by NASA, and is on schedule for launch and experimentation in 1989. ACTS will allow a large number of U.S. companies, universities, and government agencies to experiment with spot beams, hopping beams, and switchboard in-the-sky concepts that will enter the marketplace by the mid-1990's.

Mobile Satellite. Satellite-aided communications from cars, trains, buses, and other mobile platforms have been one of the unfilled promises of modern technology. Such a communications system would augment planned terrestrial service in non-metropolitan areas of the United States and thus provide a truly ubiquitous, nationwide network. Applications include emergency response communications needed in wide-area law enforcement, national disasters, medical services, and numerous business and commercial endeavors such as interstate trucking and remote oil and gas well drilling operations. By mid-1985, the FCC had received 12 applications to build a mobile satellite. It is currently in the process of allocating a domestic frequency for mobile satellite service.

In 1984, through agreements with U.S. industry and Canada, NASA initiated a program that will help industry provide commercial mobile communications by the end of the decade. This program was in direct response to the President's policy on the commercial use of space to develop new hardware markets, businesses, and service industries. In 1985, NASA continued to investigate technologies related to frequency spectrum and orbit resources so important to the future growth and economic viability of communications. Important examples of these technologies include higher gain vehicle rooftop antennas, low data rate digital voice, and multibeam spacecraft antennas that can reuse the allotted frequencies many times. A special feature of the technology development is a 55-meter antenna that can be unfurled in space; such an antenna is generic to giant antennas now planned for the Space Station era. In addition, NASA is working with other government agencies on an experimental program that would help them determine the usefulness of mobile satellite service for their operations.

Search and Rescue. In 1985, the COSPAS/SARSAT system began an era of regular operation. The international cooperative program has demonstrated the success of satellite technology to detect and locate aircraft and vessels in distress. The technical performance of the combined satellite and ground system has equalled or exceeded expectations of sensitivity, accuracy, and ground coverage. By late 1985, the use of the system in real distress operations had resulted in saving more than 510 lives throughout the world. There is wide international participation in the system which has resulted in reduced costs and a broad sharing of the benefits. The United States, Canada, France, and the Soviet Union developed the system; and Norway, the United Kingdom, Sweden, Finland, Bulgaria, Denmark, and Brazil also participate.

ATS-1 and ATS-3. In 1985, ATS-1 began drifting eastward. It would no longer respond to station keeping commands. On August 1, 1985 ATS-1 was shut down to prevent interference with ATS-3. Congress asked NASA to investigate options to replace ATS-1 in the Pacific Basin; a report on viable ATS-1 replacement options has been forwarded to Congress. ATS-3 continues to support the National Science Foundation, NOAA, the Departments of Defense and Interior, the Drug Enforcement Administration, several universities, state and local governments, and a number of domestic and international disaster relief organizations. ATS-3 is a useful communications tool in support of relief efforts, such as those that occurred after the earthquake in Mexico City and the volcano eruption in Columbia.

Optical Intersatellite Links and Other Component Techniques. NASA is involved in advanced research in which solid state and electron device power amplifiers, and monolithic receivers and power amplifiers are being developed. A major effort continues to develop laser communications for intersatellite links between geosynchronous and low Earth orbiting spacecraft, and for deep space communications that places a gallium arsenide laser transmitter and receiver on both the Shuttle and the ACTS satellite. A link would be established, around 1990, providing a 300 Mbps optical communications channel between ACTS and a vehicle in low Earth orbit. This would demonstrate the interoperability of optical and RF communications technologies.

Space Station. NASA initiated contracts in 1984 to configure and design a Space Station for future construction and integration in space. NASA's Communications Division has been very active in determining missions to use the Space Station, including geostationary platforms, advanced mobile communication satellites, an antenna and payload test range and, in conjunction with NOAA, advanced search and rescue technology tests.

Geostationary Platforms. In 1984, NASA awarded four contracts on geostationary platforms to U.S. industries; two were directed toward aggregate payload definition and two were for towbus definition. These four contracts were essentially completed in 1985 and provide both alternative traffic scenarios and bus and payload designs for the alternative scenarios; this reflects the growing demand for geostationary arc usage by both communication and science users, and for use of the Space Station and the Shuttle to provide a platform assembly base in low Earth orbit before transfer of the platform to geostationary orbit.

Environmental Observations

Advanced instrumentation, in the form of more complex sensors and satellites, provides increasingly refined information about the Earth's atmosphere and environment and helps us to understand the processes that affect them.

Upper Atmosphere. In cooperation with its Brazilian counterpart space agency, INPE, in July and August 1985, NASA conducted a joint atmospheric chemistry and meteorology experiment in the Amazon rain forest to study the forest as a source and sink region for important atmospheric gases and aerosols, and to investigate the mechanisms of exchange between the boundary layer and the free troposphere over the forest. The experiment involved more than 100 U.S. and Brazilian scientists operating instrumented micrometeorology towers located in the forest, tethered balloons, ground-based chemical flux instruments, radiosondes, ozonesondes, and satellite weather data receivers. Called the Global Troposphere Experiment/Amazon Boundary Layer Experiment, this mission examined one of the largest and most interesting ecological systems in the world from the standpoint of its influence on the global environment. U.S. and Brazilian scientists also conducted tests aboard a NASA Electra research aircraft operating over the forest during the mission. The experiment was designed to test hypotheses that account for unusual distributions of carbon monoxide off the northwest and northeast coasts of South America that were observed by a sensor aboard the second Space Shuttle flight in 1981; a second ground-based and aircraft campaign is planned for 1987. A third experiment near the end of the decade will be planned to coincide with a reflight of the Shuttle-based sensor.

During 1985, NASA coordinated efforts to prepare a comprehensive report assessing the current state of knowledge of the process which controls the distribution of atmospheric ozone and its susceptibility to change due to natural and anthropogenic perturbations. This assessment is being co-sponsored by NASA, FAA, and NOAA, and by the World Meteorological Organization, the United Nations Environmental Program, and the Federal Republic of Germany. Approximately 150 scientists from 11 countries have contributed to the assessment. It includes, among other topics, the physical, chemical, and radiative processes which control the spatial and temporal distribution of ozone in the troposphere and stratosphere; the magnitude of natural and industrial sources of substances capable of modifying atmospheric ozone; the predicted magnitude of ozone perturbations for a variety of emission scenarios involving a number of substances changing both individually and together; the predicted climate change for the same trace gas scenarios used to predict ozone perturbations; and the ozone and temperature data used to detect the presence or absence of a long-term trend.

One major conclusion of the assessment is that the increasing atmospheric concentrations of gases such as chlorofluorocarbons, methane, nitrous oxide, and carbon dioxide are predicted to perturb the temporal and spatial distribution of ozone with potential consequences for the global climate system.

Interdisciplinary Research. In 1985, NASA initiated the Interdisciplinary Research program in Earth Science, to investigate and understand long-term physical, chemical, and biological changes in the Earth's environment on a global scale. Similar investigations are being conducted under existing NASA programs in upper atmospheric research, atmospheric dynamics and radiation, oceanic processes, global biology, tropospheric chemistry, air quality and climate, and land processes. The Interdisciplinary Research Program focuses on advancing research in important areas cutting across these existing discipline areas. In consultation with the scientific community, three specific areas have been selected for emphasis in the new program, based on their importance to science: research to understand the origins and consequences of increases in atmospheric concentrations of methane; research to understand the extent to which changes are taking place in climatologically important properties of land surfaces; and studies to develop a better understanding of the magnitude and variability of oceanic carbon fluxes on a basin to global scale.

Geodynamics. Direct measurements of the movement of the tectonic plates that make up the crust of the Earth have been obtained by the NASA Geodynamics program, using laser ranging to special satellites such as the Laser Geodynamics Satellite (Lageos), and using very long baseline microwave interferometry (VLBI), a technique pioneered by radio astronomers. These measurements constitute a key test of the plate tectonics theory.

The new VLBI data show, for example, that North America is moving away from Europe at a rate of 1.3 centimeters per year; and this and the observed relative motion of other pairs of plates are in good agreement with the predictions based on the geological record, averaged over millions of years. Continuation of these observations for longer times should result in information on how the dynamics of the Earth's interior affect the rate of motion of the plates.

Satellite laser ranging observations of the Lageos satellite are being used in California to measure the gross motion across the San Andreas Fault. Measurements from 1972 until about 1981 showed the motion across the fault, which is the boundary between the Pacific and North American plates, to be about 6 centimeters per year. During the last few years the rate of motion appears to have decreased significantly to a level of only about 3 centimeters per year. This new rate of motion has been confirmed by measurements made by VLBI. The change is of considerable scientific interest and represents the first time a possible change in deformation and strain accumulation has been observed by the space techniques. The implications of this change in motion may relate to the probability of the occurrence of earthquakes in the western United States. Measurements by both lasers and VLBI are continuing in many parts of California and the western United States in an attempt to determine the extent of the motion, and to understand better the causes of the observed motions and the geophysics of crustal deformation in an earthquake prone area.

The Italians are developing a second Lageos satellite to be placed in orbit by the Shuttle in the late 1980's to early 1990's. Lageos II will be identical to its predecessor. It will orbit at the same 6000-km altitude, but with an inclination of 52 degrees instead of the 110 degrees for Lageos I. This lower inclination will be optimum for the Mediterranean and other lower latitude laser stations. The addition of Lageos II is expected to improve, by a factor of two, the accuracies of the geodetic quantities produced by Lageos I alone. Tracking of the two satellites will greatly enhance research in the areas of plate tectonics, crustal deformation, and Earth dynamics.

In addition to the laser and VLBI techniques discussed above, NASA and other agencies are developing the use of the DoD Global Positioning Satellites (GPS) for geodetic measurements. A NASA developed GPS receiver called SERIES (Satellite Emission Range Inferred Earth Surveying) partipated in interagency comparison tests with two other receiver systems in the desert of southeast California in early 1985. The use of low cost, portable GPS receivers for a highly accurate measurement of vector baselines will introduce a new era in geodesy. A number of important geophysical questions can now be addressed with this measurement capability, due to the large number of observations which can be made economically with a GPS-based system. NASA's goals for this program are to design and demonstrate a GPS-based measurement system for centimeter geodesy and to accumulate scientifically important data in a key tectonic region, such as Central America and the Caribbean. An additional goal is to develop an active participation in GPS-based geodetic programs by scientific groups residing in North America, the Caribbean, and Latin America.

Land Observations. The Land Processes program includes studies relating to the conditions of the terrestrial surface and the processes which control them. The research, which is concentrated on those processes involving changes in the terrestrial surface on continental to global scales, includes the geologic and hydrologic sciences as well as the study of terrestrial ecosystems and biogeochemical cycles. Typical activities are theoretical modeling, field experiments, sensor development, and analysis of data from satellite and aircraft sensors. The major data sources are the Multispectral Scanner and the Thematic Mapper on Landsat-5, the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's operational weather satellites, and a variety of aircraft and Shuttle experiments.

As the transfer of the Landsat system to the private sector was being made in accordance with the Land Remote Sensing Commercialization Act of 1984, NASA completed a 2-year study of the performance of the Thematic Mapper and initiated a new science investigations program using the sensor. The new science program complements the emphasis on nearer term applications which characterized the program in the past. Key studies include investigations of the tectonic evolution of the Brooks Mountain Range in Alaska, of desertification in Mali and Botswana, and of the West Antarctic Ice Sheet.

The sensor development program is aimed at developing the next generation systems for scientific and commercial use in the mid-1990's. It consists of a set of combined airborne and spaceborne systems operating the visible, infrared, and microwave regions of the spectrum. In the visible region, an airborne system, the Advanced Visible and Infrared Imaging Spectrometer is nearing completion, while a more powerful Shuttle-borne system, the Shuttle Imaging Spectrometer (SISEX), is in the initial stages of development. These instruments will provide high spectral resolution information about the land surface, permitting identification of mineral species and determination of plant condition. Another airborne instrument, the Advanced Solid State Array Spectrometer, is optimized to provide diagnostic information on the directional reflectance from the land surface for use in climatic studies and forest composition studies. SISEX will include similar capabilities, thereby increasing its utility. Information in the thermal infrared portion of the spectrum provides additional unique information about surface mineralogy and stress conditions in vegetation. The recently developed airborne Thermal Infrared Multispectral Spectrometers are used for studies of this type.

The ability of synthetic aperture radars to obtain imagery through clouds makes them valuable tools for studying deforestation in the tropics. The use of multiple views of the same scene permits stereoscopic measurements of topography, while the strength of the signals at various wavelengths allows estimates of surface roughness. These are powerful aids to the study of surface geology. Analysis of the data returned by the Shuttle Imaging Radar mission in 1984 continues. An airborne dual-wavelength, four-polarization imaging radar system which was used to prepare for a more advanced Shuttle mission in 1989 was destroyed in the crash of the NASA CV-900 airborne laboratory. An effort to rebuild the system is underway.

Studies of the interannual variations in African grassland productivity using the AVHRR continued in 1985. The increased productivity due to abundant rainfall is apparent in the data. Detailed studies and ground verification are underway. Related theoretical studies will use the data in physical modeling of the exchange of energy and water in these regions, which are subject to desertification. Observations from the Scanning Multifrequency Microwave Radiometer, also on the NOAA satellite, are expected to be equally important.

Field experiments to increase our understanding of stress in natural vegetation are underway. The major activity is in the forests of Vermont where acid deposition is apparently causing damage. Using high spectral resolution sensors from a helicopter and a variety of sensors aboard NASA's C-130 research airplane, investigators are finding spectral indicators of damage which should lead to earlier detection and identification of the most sensitive areas.

Considerable progress has been made in the study of the interaction between the land surface and the climatic system. For the first time, an interactive biosphere has been incorporated into a General Circulation Model of the atmosphere. Studies are underway which use the new model to investigate the role of vegetation through its influence on surface roughness, evapotranspiration, and interception of rainfall. At the same time, the International Satellite Land Surface Climatology Project will conduct a major experiment in 1987 to better relate satellite measurements to climatically important changes in the land surface. The experiment will take place in the Konza Prairie. In preparation for the experiment, U.S. investigators will participate in a related French experiment in 1986.

A major advance was made in the use of multispectral imaging systems when investigators using the Airborne Imaging Spectrometer found a little-known mineral, Buddingtonite, in one of their studies. Ground readings did not distinguish this mineral from a variety of others. Only after its spectral signature was noted in the aircraft data, was it identified. This is a major step forward. Previously, using lower spectral resolution devices, selected minerals could be distinguished from one another, but conclusive identification was not possible.

Operational Meteorological Satellites. At the end of 1984 NOAA-9 replaced NOAA-7 as NOAA's operational afternoon (2:30 p.m. local time) spacecraft. NOAA-9 is the second of the advanced TIROS-N spacecraft. These spacecraft are a "stretched" version of the original TIROS-N series and provide expanded capabilities to handle additional operational and R&D instruments. NOAA-9 is the first operational spacecraft to carry solar backscatter ultraviolet radiometers to provide global measurements of atmospheric ozone concentration for both NASA research and NOAA operational objectives. NOAA-9 also carries the Earth Radiation Budget Experiment intended to measure the Earth's radiation balance between incoming and outgoing energy. The data will be used in support of climate research activities.

Due to a conflict with an Air Force mission, the launch of NOAA-10, intended to become NOAA's operational morning (7:30 a.m. local time) spacecraft, was postponed until 1986. Plans also continued to launch GOES-7 in May of 1986. GOES-7 is a geosynchronous weather satellite that will provide east coast coverage, replacing GOES-5, which failed during the summer of 1984. Until then, GOES-6 will be operating at mid-country to provide round-the-clock imagery of the continental United States.

A contract was signed with Ford Aerospace to build three next generation geosynchronous weather satellites. The contract covers the construction of these spacecraft plus an option for two more. The first of the new series will be flown in late 1989 or early 1990. They will be Shuttle launched and provide independent imaging and atmospheric sounding capabilities.

Climate

Climate Research. During the past year, the Earth Radiation Budget Experiment (ERBE) has been receiving and processing data both from the Earth Radiation Budget Satellite, launched in October 1984, and from ERBE instruments aboard the NOAA-9 operational meteorological satellite, launched in December 1984. A third set of identical instruments is expected to be launched aboard the NOAA-G spacecraft in early 1986. Although most of the activity during the past year has been devoted to validation of the ERBE results, some interesting scientific results are emerging. One example is the measurement of the "solar constant," or solar irradiance at the mean distance of the Earth from the Sun.

The International Satellite Cloud Climatology Project (ISCCP) is continuing to collect and process data on the global distribution of cloudiness. Uncertainties in the geographical and temporal distributions of clouds are recognized as a major impediment to improved climate prediction. The

ISCCP entered its second year of operations on June 30, 1985, collecting data from the international array of operational polar orbiting and geostationary satellites. NASA continues to play a major role in the ISCCP through its support of the Global Processing Center, which serves as the hub of international operations.

Planning has also continued in support of Project FIRE (First ISCCP Regional Experiment), a multiagency U.S. sponsored research program whose goals are: to seek a better understanding of the roles played by physical processes in controlling the life cycles of climatically important cloud systems, to improve the parameterization of clouds in climate models, and to contribute to a validation of the ISCCP cloud climatology on a regional basis. The national project office for FIRE, located at NASA's Langley Research Center, issued an implementation plan in 1985 describing a series of data gathering and modeling activities which focus on cirrus and marine stratocumulus cloud systems, both of which are believed to be important to the Earth's radiation budget and climate. This plan will be implemented by a university/government science team over the next few years, with primary support from NASA, NSF, NOAA, DOE, and DOD.

Global Scale Atmospheric Processes. Advanced techniques, both active and passive, for satellite observations of the Earth's atmosphere are being developed. The active remote sensing techniques apply both laser radars and microwave radars to sensing atmospheric parameters. Emphasis is placed on the application of laser techniques in anticipation of their potential to overtake present technology. Several of these laser techniques were tested on aircraft platforms during 1985 to observe, remotely, atmospheric temperature, pressure, and moisture profiles. As a result of present and planned airborne experiments, the scientific justification and engineering requirements for these instruments will be developed to permit their use on future experimental space platforms. Additional laser techniques being developed use coherent laser radars to observe wind profiles. A preliminary design study for a coherent laser radar wind sensor on the Shuttle was completed in 1985. This study provided positive indication of the viability of this next step in developing a satellite global wind sensor.

Analysis approaches have been developed to use the passive, multispectral data obtained from instruments on operational meteorological satellites. Application of these extensive analyses has produced global maps of a number of parameters descriptive of processes on the Earth's surface and atmosphere. Further use of the operational data to test the limits of their information content will provide useful guidelines needed to develop the next generation sensor for operational use.

Computational techniques to model physical processes in the Earth's atmosphere have improved in step with the development of computational hardware. Through this NASA program, computational techniques are being developed to improve use of satellite data to understand large-scale atmospheric processes. Through impact studies using the models developed, satellite data have been shown to augment effectively conventional meteorological data, especially in data sparse, oceanic regions. These data sparse regions cover more than one-half of the Earth's surface area. The computational models of the large-scale motions in the Earth's atmosphere have been used to guide the development of future satellite sensors. Model studies completed and reported in 1985 show that satellite observations of global wind profiles will dramatically improve our understanding of large-scale atmospheric processes. This improved capability to observe atmospheric motions and atmospheric moisture will increase our understanding of that portion of the hydrological cycle.

An experiment to model fundamental fluid dynamical processes in planetary atmospheres was flown as part of the Spacelab-3 payload launched in 1985. The experiment met or exceeded its objectives and provided a wealth of data to be analyzed over the next several years. Early analyses have indicated that these data may provide information to help understand questions as diverse as the cause of Jupiter's red spot or the dynamics of the solar chromosphere. Due to the success of this Geophysical Fluid Flow Experiment, and the large number of additional case studies in which it could be used, scientists hope that it will be a candidate instrument for inclusion on future Spacelab missions.

Mesoscale Research. This atmospheric research and development program stresses the understanding of severe weather and the environmental influences which cause it. There is strong use of simultaneous data from various satellite sensors, high-altitude aircraft remote sensing missions, ground-based Doppler radars, and wind and temperature profilers, as well as of conventional weather information. New techniques are being developed to use remote sensing to identify deadly downdrafts called microbursts and tropical cyclones; to make storm surge calculations leading to more precise warnings; to determine land surface and vegetation influences on local storm development; to provide rainfall estimates leading to improved flood warnings; and to identify the trigger mechanisms for surprise east coast winter storms that leave paralyzing amounts of snow that cripple commerce in the major cities.

Some of the specific science experiments which led to the above technology applications involved numerous flights of aircraft with microwave, optical, and infrared sensors to study cloud structure, radiative processes, and lightning emissions, as well as the land-surface and atmospheric environments producing the cloud development. Precipitation estimation has been a focus of remote data interpretation efforts, since interest in the value of accurate rainfall estimates is worldwide.

Two international developments are of significance in this area. First, a multimillion dollar Agro-Climatic/Environmental Monitoring Center was implemented by NASA for the U.S. Agency for International Development in Bangladesh. This facility received and processed a wide variety of atmospheric, oceanic, and land remote sensing data for resource management and disaster warning purposes. A little known fact is that during the killer cyclone which hit Bangladesh in May 1985, approximately 10,000 lives were saved because the newly-installed NASA system was able to pinpoint the islands which were about to be hit. This was confirmed by a New York Times reporter on the scene. The second development is work with India on a cooperative remote sensing experiment an Indian payload specialist will perform aboard the Shuttle during the INSAT-C mission. Mesoscale cloud, climate, and land classification data will be obtained.

Extensive multi-agency coordination efforts were made in preparation for two mesoscale meteorological field experiments: the Genesis of Atlantic Lows Experiment and the Satellite Precipitation and Cloud Experiment. Significant quantities of satellite and high-altitude remote sensing will be conducted during each of these 1986 experiments.

Oceanic Processes. In oceanography, NASA is developing the Scatterometer (NSCAT) for flight aboard the Navy Remote Ocean Sensing System. The Announcement of Opportunity for selection of scientific investigators to utilize NSCAT data was issued and responses are currently under review. In addition to NSCAT, 1985 budget approval covered the establishment of an Alaskan SAR Facility to receive and process synthetic aperture radar (SAR) data from the European Space Agency's ERS-1 satellite, due to fly in 1990.

The second element of the above research strategy is the Ocean Topography Experiment (TOPEX), a dedicated altimetric satellite which may be proposed as a high-priority new start in the 1987 budget in a joint mission between NASA and France. The third element is the proposed Ocean Color Imager (OCI), an improved version of the Coastal Zone Color Scanner currently flying aboard Nimbus-7. The NOAA K, L, and M series of spacecraft have been considered for an OCI.

If flown with significant overlap in time, these three missions – TOPEX, NSCAT, and OCI – will permit global observations of atmospheric wind forcing, ocean current response, and associated phytoplankton productivity, respectively. They are key elements of the World Climate Research Program, proposed for initiation in the early 1990's. Observations from these three missions will permit, for the first time, an assessment of the interdepedence of atmospheric and oceanic variability, and its collective influence on the Earth's climate.

Information Systems

The Information Systems Office (ISO) manages a data systems program to serve the data management and information processing needs of the Office of Space Science and Applications (OSSA). In 1985, ISO's computer networks allowed real time science analysis during the International Cometary Explorer encounter, and its advanced processing systems and data bases supported modeling and analyses for the oceans, planetary, and climate programs. In general, ISO programs complement the data systems capabilities developed by OSSA flight projects.

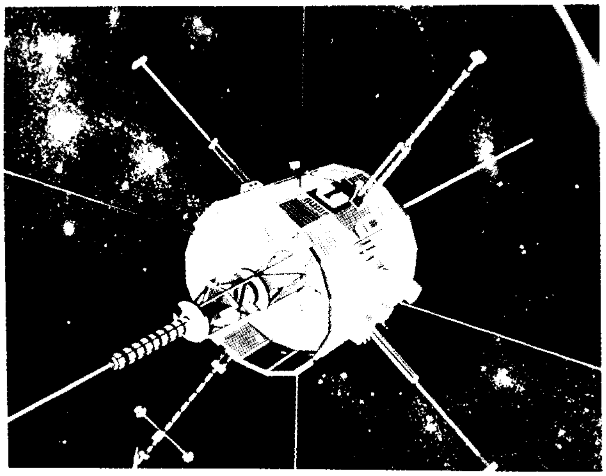
The systems and technologies developed by ISO are transferred upon completion to the host discipline programs for their subsequent operational use, possibly as part of the data systems of new flight projects.

Though relatively small, the ISO organization is a vital part of OSSA's total program, providing essential technologies, tools and techniques to enable more productive scientific research through improved access to, utilization of, and management of space-acquired data.

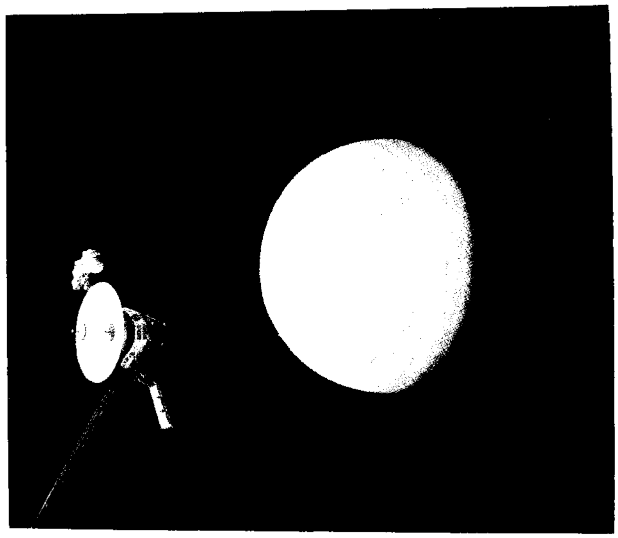
The Information Systems Office serves as a focal point within OSSA to identify and coordinate data system requirements common among all the OSSA disciplines, and to develop generic information system capabilities which can be shared among discipline programs. ISO also represents agency-wide interests and can apply its broad experiences to specific OSSA disciplines and flight projects.

Space Science

During 1985, studies of the nature of the universe and solar system were highlighted by the exciting first spacecraft encounter with a comet. Preparations also continued for the Voyager 2 spacecraft's flyby of Uranus.



The International Cometary Explorer intercepted Comet Giacobini-Zinner on September 11, 1985.



Voyager 2 on its approach to the planet Uranus.

Solar System Exploration

Preparations were underway for several major events – the Voyager 2 encounter with Uranus, the appearance of Halley's Comet, and the launch of Galileo and Ulysses missions toward Jupiter. Active development continued on the Venus Radar Mapper and the Mars Observer. Also, Pioneer Venus and other Pioneer spacecraft continued to collect and transmit data.

Cometary Studies. On September 11, 1985, after the most complicated orbital maneuvers every performed by a spacecraft, the International Cometary Explorer (ICE), intercepted Comet Giacobini-Zinner, passed through the comet's tail and provided the first spacecraft data on a comet's magnetic field, plasma environment, and dust content.

The active study of the more famous Comet Halley has already begun. The appearance of this comet, and its close approach to the Sun that will occur between February and April 1986, are generating more public and scientific interest than any celestial event in recent years. Comet Halley will be the focus of observations made from the ground, by spacecraft from Earth's orbit, and from sounding rockets. Five spacecraft from Europe, Japan, and the USSR will fly past the comet in March. The comet will also be observed at long distance by the U.S. ICE and Pioneer Venus spacecraft. The International Halley Watch, a ground-based network of 900 observatories in 47 countries, will insure nearly continuous observation of the comet as it passes through the inner solar system.

Voyager at Uranus. During 1985, intensive preparations were completed for the first spacecraft encounter with the distant planet Uranus, by Voyager 2 in January 1986. Uranus is already known as a unique planetary system, with five known moons, at least nine rings, and a rotational axis so highly tipped that the planet appears to lie on its side relative to other planets.

In September, 1985, the spacecraft obtained images of Uranus, its satellites, and its rings, the first such pictures ever made by a spacecraft. Also, measurements of the plasma and magnetic fields showed the magnetic field of Uranus to be much weaker than expected.

On its historic flyby through the Uranus system, Voyager 2 will pass within 30,000 kilometers of the smallest moon (Miranda) and within 107,000 kilometers of the planet's cloud tops at 1:00 p.m., January 24, 1986. A variety of new tracking, communications, and operations procedures have been established in order to allow collection of data from this planet, located more than 2 billion miles from Earth. Leaving Uranus, Voyager 2 will pass near the planet's outermost ring and then travel on a trajectory toward the planet Neptune, which it will reach in August, 1989.

Pioneer Venus. Due to continual change in orientation of the spacecraft orbit, instruments on the Pioneer Venus Orbiter spacecraft, in its sixth year of operation, were able to make significant new measurements of the solar wind interaction with Venus. The first measurements of electric field disturbance and elevated plasma densities were obtained at the subsolar Venus bowshock zone, a region not previously accessible to direct probing. A guest investigator on the mission, studying the nightside ultraviolet imaging data, unexpectedly discovered aurorae in the Venus atmosphere known as "Northern Lights." No explanation has yet emerged to explain how these spectacular and powerful emissions can be produced on a planet with no magnetic field.

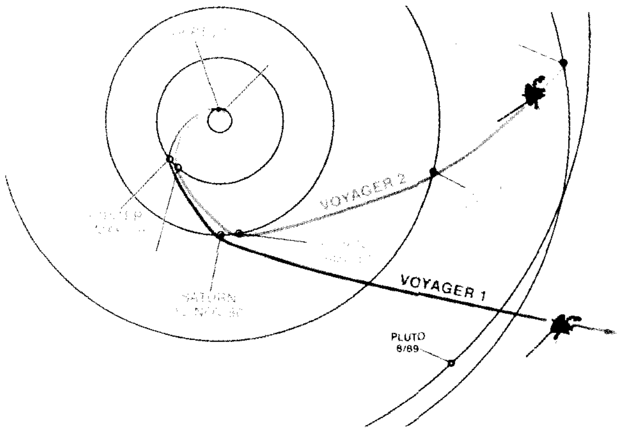
The Pioneer Venus spacecraft also has a new role in comet studies. Following the observations of Comet Encke in 1984, the spacecraft was reoriented in September, 1985 so that the Ultraviolet Spectrometer instrument could observe Comet Giacobini-Zinner for ten hours during the ICE spacecraft's encounter with it. This has resulted in a better determination of the rate of water evaporation from the comet. Similar, and more extensive, observations of Comet Halley are planned for January-March, 1986.

The Interplanetary Medium. Extensive studies of the interplanetary medium were made by four spacecraft – Pioneers 10 and 11, Voyagers 1 and 2 – in the outer solar system during 1985. Pioneer 10, traveling through the Milky Way Galaxy in a direction opposite the motion of the Sun, is now 37 astronomical units from the Sun, well outside the orbit of Neptune, the outer boundary of the solar system itself. The spacecraft continues to return data with the aim of detecting the heliopause, the boundary between the Sun's magnetic influence and interstellar space. Pioneer 11, traveling in the opposite direction from Pioneer 10, is now about 20 astronomical units from the Sun, just past the orbit of Uranus.

Voyager 1 is exploring the space environment above the ecliptic, the plane of the solar system, on a path toward the star Rasalhagne. The spacecraft is now about 25 astronomical units from the Sun and has ventured farther above the ecliptic plane of the solar system than any previous spacecraft. Voyager 2 continued to observe the interplanetary medium as it approached Uranus.

Galileo to Jupiter. The major planetary mission under development is the Galileo mission to Jupiter. During 1985, several essential milestones were completed. This included development of flight software, which was successfully tested on the spacecraft. To prevent computer failures due to radiation events in space, new radiation-resistant electronic microcircuits were designed, fabricated, and installed in critical subsystems.

Ulysses to the Sun. This mission, a cooperative effort with the European Space Agency (ESA), will launch a spacecraft to and around Jupiter, and then pass closely over the Sun's south pole. During 1985, pre-launch testing of the spacecraft and instruments was completed by ESA. Because both Ulysses and Galileo are aimed at Jupiter, these two spacecraft share a 23-day launch window and both must be launched during this period if they are to proceed on a direct trajectory. The earliest they can be launched is July 1987 when Earth, the Sun and Jupiter will be in the proper alignment.



Flight paths of Voyagers 1 and 2.

Venus Radar Mapper. Under active development for a 1988 launch is the Venus Radar Mapper spacecraft, which will use orbital radar to map the cloud-shrouded surface of the planet Venus. During 1985, critical reviews were completed on the radar sensor, the spacecraft, and ground data processing systems. These reviews were essential before fabricating the flight hardware. Also, an improvement in the ground resolution of the radar sensor was incorporated into the plan and design; this improvement will make possible the detection of surface features twice as small as originally planned.

Mars Observer. Scheduled for launch in 1990, the Mars Observer mission will place a spacecraft in orbit around Mars in 1991, for a full Martian year (687 days), to study aspects of that planet's surface geoscience and climatology. During 1985, proposals were solicited and received for both the Shuttle-launched Mars Observer spacecraft and the scientific investigations that it will carry. Selection of both spacecraft and investigations is planned for early 1986.

Flight Support. Significant modifications in the Flight Support and Missions Operations Systems have been carried out in order to respond to requirements of current and future missions in a systematic and cost-effective way. In 1985, final development and upgradings were completed to support testing of the Ground Data Systems for the Voyager, Galileo, and Ulysses missions. In support of spacecraft missions to Halley's Comet, commanding capabilities were provided to support the launch of ESA's Giotto spacecraft in July, 1985. Tracking and telemetry acquisition support were also provided for the USSR Vega missions to Venus and Halley's Comet.

Advanced Programs and Planning. Efforts continue to identify and characterize possible future planetary missions and to identify critical technology needs for such missions. Current studies have been based on the recommendations of the Solar System Exploration Committee, which recommended a "Core Program" in 1983. The recommendations included two new classes of spacecraft: Planetary Observers for near-Earth missions and Mariner Mark II spacecraft to explore the outer solar system.

The Planetary Observer series was initiated in 1985 with the Mars Observer mission, and several candidates for the second Planetary Observer mission were studied: a Lunar Polar Orbiter to map the Moon and to search for frozen water near the lunar poles; a Near-Earth Asteroid Rendezvous to study scientific problems and to categorize the resource potential of one of several asteroids that repeatedly approach the Earth; and a Mars Aeronomy Observer to study the upper atmosphere of Mars and the interaction of the solar wind with the Martian environment.

The first Mariner Mark II mission recommended by the Committee is a Comet Rendezvous/Asteroid Flyby (CRAF) mission that would fly past an asteroid and then rendezvous with a comet for extended observation and study. One possible mission would involve a 1992 launch to the Comet Tempel 2, with a flyby of the Asteroid Hestia. The CRAF spacecraft design is modular and can be readily adapted to later planetary missions. Another potential mission would use a Saturn orbiter that would carry a probe to penetrate the atmosphere of Saturn's largest moon, Titan. During 1984 and 1985, NASA and ESA studied this latter mission, named Cassini, and developed a mission concept in which the Mariner Mark II Orbiter would be mated with an ESA-developed Titan probe to form a single mission.

Space Plasma Physics

Plasmas exist from just above the Earth's atmosphere, through the Earth's magnetosphere to the solar atmosphere, and into the atmospheres and magnetospheres of the other planets. Space plasma research involves both in situ measurements of natural plasma environments and active plasma experiments to simulate plasma phenomena.

In 1985, the National Academy of Sciences completed a study entitled "An Implementation Plan for Priorities in Solar-System Space Physics" which proposes a systematic plan of solar and space plasma physics research until 1995. It gives the International Solar-Terrestrial Physics (ISTP) program the highest priority, and supports efforts to define the U.S. contribution through use of satellites, instruments, data handling and modeling. Planning for the program is by the Japanese Institute of Space and Astronautical Science (ISAS) and the European Space Agency (ESA). ISAS is developing the Geotail spacecraft designed to explore the geomagnetic tail of the Earth. ESA continues to develop the solar-terrestrial cornerstone of the Solar and Heliospheric Observatory (SOHO), a solar pointed spacecraft to measure basic physical processes of the Sun, and Cluster, a set of four spacecraft to study basic plasma phenomena; and NASA is pursuing an initiative which would support all three missions with instruments, tracking and ground data processing. In addition, NASA plans to launch Geotail and one ESA mission.

The IMP-8 satellite is about 12 years old, but continues to monitor solar wind in the Earth's magnetosphere, and provides a crucial baseline for missions to the outer planets.

Support of the International Sun-Earth Explorers satellite program, begun in 1977, continues; over 100 scientific papers per year have been published, including many of the study of collisionless plasmas and fields.

In 1985, the International Cometary Explorer passed within 8,000 kilometers of comet Giacobini-Zinner's nucleus through the middle of the ion tail. The comet was found to be extremely active in the area of plasma physics. The ion tail model of dual lobes of opposite polarity separated by a neutral sheet was verified; dust levels were several orders of magitude less than the predicted rate.

The Dynamics Explorer 2 (DE-2) spacecraft reentered the atmosphere after providing considerable amounts of information since its launch in 1981; DE-1 continues to provide new data on ionosphere-magnetosphere interactions and auroral morphology, as well as on global airglow and ozone measurements.

In 1985, the Active Magnetospheric Tracer Explorer completed its primary mission, or active phase, and began its extended mission, or passive measurement phase.

Work continues on the Combined Release and Radiation Effects Satellite that involves release of chemicals from 48 canisters located on the satellite. Measurements are made from ground-based, airborne and satellite instrumentation to determine the origin, energization and flow of plasma in the magnetosphere.

Investigations have been selected and defined for the first tethered satellite mission, a joint program with Italy. This first mission will investigate the electrodynamical interaction between the 20 kilometer tether wire and the ambient plasma.

Payload development continues for Earth-observing missions, and for the Space Plasma Laboratory, all of which will make use of the Shuttle. Instrumentation developed for these missions will eventually become part of the Space Station Solar-Terrestrial Observatory.

In 1985, 22 space plasma physics sounding rockets were launched to study properties of the middle atmosphere and the auroral regions. One particularly successful campaign was conducted in Greenland with Danish scientists. The rockets returned data on plasma flow, plasma turbulence, electric fields and coupling from the polar ionosphere to the middle atmosphere.

Through the Research and Analysis program, 65 grants and contracts were funded with universities and private industry, and 45 additional projects were funded through five NASA centers. They covered a broad range of topics in space plasma physics, and considerable information was discovered. A notable example is the "Global Solar-Terrestrial Electrostatic Coupling Study" by the National Center for Atmospheric Research, in which electrodynamic effects of the Earth's thermosphere are included in a global circulation model. The results show important interactions between the ionospheric wind dynamo, the solar wind/magnetosphere dynamo and thermospheric neutral wind systems. Implications of such interactions for proposed Sun-weather connections and other important problems will require continued monitoring of these electrodynamic systems.

Study of the Universe

NASA's Astrophysics program investigates the physical nature of the universe, from our own Sun to the most distant quasers, in order to determine the laws that govern cosmic phenomena, to understand the Sun as a star, and to learn how the universe began and how it will end. Many observations cannot be made through the Earth's atmosphere, so instruments for such observations must be carried above the atmosphere into space.

High Energy Astronomy Observatory (HEAO). During 1985, data from the High Energy Astronomy Observatories contributed substantially to our understanding of high energy astrophysical processes. A continuing, detailed analysis of the HEAO-2 data, for example, has revealed the existence of x-ray "haloes" surrounding the optical disks of normal galaxies. While a definitive determination of the origin of this x-ray emission must await the launch of a future x-ray facility, present observations indicate the presence of a significant amount of "dark matter" in otherwise normal galaxies. The HEAO-3 analysis has demonstrated that the relative abundance of lead and platinum in the cosmic radiation is different from the abundance in the solar system. Taken at face value, this indicates that the chemical evolution of the solar system material is different from that of the cosmic ray sources. A vigorous Guest Investigator Program has involved the broader astronomical community, which has enhanced the quality of analysis and interpretation of the HEAO data.

Gamma Ray Observatory (GRO). In 1985, substantial progress was made in the design and development of the Gamma Ray Observatory, which is scheduled for launch in 1988. The design was completed and the critical design review of the observatory was conducted. The mission contractor began manufacturing the GRO structure and mechanisms, and built the large 30-inch aluminum I-beams in the GRO platform. Fabrication of all hardware for the four GRO scientific instruments was nearly completed, and assembly and testing began.

Solar Maximum Mission (SMM). Most of the Solar Maximum Mission's instruments continued normal operations, making valuable new observations on flares, eruptive prominences and the global solar corona. Observations obtained with the Coronagraph/Polarimeter allowed the study of the corona's global evolution, as the solar cycle reached its minimum, and the comparison of this cycle with coronal features observed on a Skylab mission during the solar cycle's previous minimum. The Active Cavity Radiometer Irradiance Monitor continued to observe small fluctuations in total solar output. Now established is an unambiguous correlation of such fluctuations with individual active regions on the solar surface. The declining trend of the total output of the Sun, which was previously observed, continues and remains unexplained. Continued operation of SMM into the declining phase of the solar cycle will allow monitoring the total flux, and determining when it begins to increase once again. This measurement is of critical importance in understanding a number of mechanisms related to the solar cycle.

Explorers. If the SMM is retrieved from space, it could be reconfigured into an Explorer platform to accommodate Explorer scientific payloads. However, since recovery of the SMM is uncertain due to a backlog of Shuttle launches, the possibility of building a new Explorer platform using the SMM design also is being explored. In addition, the approach of using an existing NASA satellite as a reuseable spacecraft bus for Explorer missions is being investigated. To maintain maximum flexibility, both the retrieved and new Explorer platforms would be compatible with a Shuttle and a Delta launch vehicle. The first potential payload, the Extreme Ultraviolet Explorer (EUVE), is under development at the University of California at Berkeley. Upon completion of the EUVE mission, the Shuttle would rendezvous with the EUVE's Explorer platform and replace the EUVE payload with the X-ray Timing Explorer. This reusable spacecraft approach will be cost-effective and will provide a defined interface for future Explorer scientific instruments.

Analysis of data from the Infrared Astronomical Satellite (IRAS), launched in January 1983, continues to yield dramatic increases in astrophysical knowledge. The largest and most detailed catalog of infrared celestial objects ever created was completed and released to the public. A new facility, the Infrared Processing and Analysis Center, was built by the California Institute of Technology as a national center where scientists can study the IRAS data and explore the infrared sky. NASA has instituted a grant program, for scientists not previously involved with the IRAS mission, to investigate the nature of celestial objects that emit much of their energy in infrared wavelengths; the program also assists astronomers seeking to understand objects at other wavelengths of the electromagnetic spectrum.

Advanced Technology Development. Phase B studies for the proposed Advanced X-ray Astrophysics Facility (AXAF) will continue through most of 1986. Data on the AXAF Program's Test Mirror Assembly (TMA) reveal that the TMA constitutes the best x-ray mirror in the world and show that the TMA mirrors can be produced. In 1985, five scientific instrument proposals were selected for definition. Definition contracts for the scientific instruments began in December 1985, and will continue for two years.

During 1985, the science working group (SWG) of the proposed Space Infrared Telescope Facility (SIRTF) was formed and instrument technology development began. In conjunction with the SWG, the SIRTF study office completed a comprehensive review of the SIRTF mission. A system study was completed, and a proof-of-concept flight demonstration and technology efforts were initiated for development of on-orbit helium cryogen transfer, a capability necessary for extending SIRTF mission lifetime to a decade or more.

Hubble Space Telescope. The Hubble Space Telescope is an astronomical observatory which will be serviced on orbit by the Space Shuttle. It will be capable of detecting and observing objects 50 times fainter and 7 times farther than is currently possible from large ground-based telescopes.

Astro. The Astro payload, consisting of three complementary ultraviolet telescopes, will fly as an attached payload on three Shuttle missions. The payload will take ultraviolet photographs and perform ultraviolet spectroscopic, photometric, and polarimetric measurements of a broad variety of celestial objects. Instrument development is complete and the Astro payload has now been fully integrated into the Spacelab Instrument Pointing System.

Spartan Program. The first flight in the Spartan program was successful. The flight systems were proven and good scientific data were obtained. Preliminary results indicate that the program will satisfy the mission's primary objectives of mapping x-ray emission from the central region of the Milky Way and the entirety of the Perseus cluster of galaxies. The results of observation of the galactic center will be used to investigate the myriad of point sources in the nucleus and, in particular, to define more accurately the nature of the central source, which is believed to be a massive black hole. Determination of the spatial distribution of emissions of ionized iron and other hot gases in the Perseus Cluster promises to yield important insight into the nature and evolution of galaxy clusters.

Two more Spartans are under construction, one for ultraviolet studies and one for solar studies. Eight additional missions have been selected for flights through 1989. International interest has been high, and several studies are underway, here and abroad, to make possible international use of this satellite.

Gravity Probe-B. Engineering test activity is underway on the proposed Gravity Probe-B instrument for flight on the Space Shuttle in the early 1990's. An outstanding team of scientists and managers has been assembled at Stanford University to conduct this testing, which will determine the feasibility of the scientific flight mission. Stanford University has subcontracted with Lockheed Corporation to enhance the Stanford technical team.

ROSAT. Progress continued to be made on the ROSAT project, a joint x-ray astronomy mission of the United States, Germany and the United Kingdom to be launched on the Space Shuttle in the early 1990's. To prepare for the U.S. role in formulating the observing plan and using the data obtained during the pointed phase of the mission, a plan for data transmittal to regional "distributed data analysis centers" has been devised.

Life Sciences

The goals of NASA's Life Sciences program are to establish biomedical foundations for permanent human presence in space and to conduct biological investigations, including study of the origin, evolution, and distribution of life in the universe.

Space Medicine. In 1985, emphasis continued to be placed on Space Shuttle operations, refinement of diagnostic techniques, medical selection of crews, and monitoring and maintaining the health and career longevity of crews. Noninvasive diagnostic techniques for assessing bone demineralization and muscle atrophy using computerized tomography and nuclear magnetic imaging, respectively, were tested.

Adaptation to microgravity involves many physiological changes. For example, an experiment conducted on Shuttle mission 51-D, in April 1985, confirmed previous information which suggested that drug effectiveness is reduced during space flight due to decreased drug absorption from the gastrointestinal tract. Alternative approaches to drug treatment in orbit are now being evaluated.

As Shuttle crews are called upon to retrieve and repair satellites, they are required to conduct more frequent and lengthy extravehicular activities (EVA's). The internal atmsopheric pressure of the EVA suit (4.3 psi) is considerably less than the Shuttle's "Earth-normal" cabin pressure (14.7 psi). As a result of this pressure differential, crews performing strenuous and frequent EVA's face the risk of decompression sickness. In anticipation of the increased EVA requirements for Space Shuttle, a special pressure chamber is being validated at the Johnson Space Center for use in designing even better EVA protocols.

Inflight investigations have continued to test the efficacy of space motion sickness treatments. Treatments such as preflight conditioning, biofeedback training, and various drugs and drug combinations show promise. Progress has also been made in developing techniques for predicting individual susceptibility to motion sickness. The Space Biomedical Research Institute was established in 1984 to seek a satisfactory solution to this operational problem. Currently, the Institute is concentrating on clinical investigations and space flight experiments to determine the etiology of space motion sickness and to devise appropriate treatments and countermeasures.

To understand how the human cardiovascular system compensates for weightlessness, researchers have conducted bedrest studies simulating microgravity. These studies offered a promising countermeasure to observed dizziness or fainting in returning space crews. A carbohydrate diet combined with several therapeutic drugs protected four out of seven subjects known to be susceptible to fainting immediately after bedrest. Other simulation studies suggest that, during flight, exercise capacity diminishes due to muscle atrophy and bone demineralization. The time separation between successive bedrests has been only two weeks, and an exercise regimen has allowed full recovery from deconditioning.

During space flight, bone loss occurs in areas of the body that provide support against the force of gravity. Previous investigations have suggested that repeated or prolonged exposure to weightlessness will lead to progressive bone demineralization. Physical countermeasures tested have thus far not been effective in preventing the loss of calcium from bedrest subjects. However, dietary supplements of calcium and phosphate are partially effective in increasing calcium retention during bedrest.

For similar reasons, it is also difficult to prevent the muscle atrophy that occurs during weightlessness. Experiments conducted in simulated weightlessness investigated the use of stretching and electrical stimulation to prevent muscle atrophy due to inactivity. Muscle atrophy was prevented by stretching the muscles in an extended position; and when stretching was combined with electrical stimulation, there was an increase in size of muscle fibers. However, since these models simulate only some aspects of weightlessness, the use of exercise, growth hormones, passive stretching, and electrical stimulation must be further tested in space.

Although the problems described above are of considerable medical concern, perhaps the most significant limiting factor on long-term manned space missions is the radiation hazard.

During 1985, sensitive dosimeters were used to monitor crew member radiation exposures and background radiation penetrating the Space Shuttle cabin. Ground-based experiments using moderate doses of radiation on the retina and brain of animals showed an increase in aging of these areas. In addition, behavioral evaluations in animals indicate brain damage that resulted in poorer scores on performance tests.

For several decades, researchers thought that the risk level from radiation was related to the amount of energy retained in tissues after exposure to radiation. Recent findings indicate that the nature of the path or track made by an ion passing through a cell also plays a role in producing cancer-causing damage. These studies add to basic understanding of radiation-induced cancer, and contribute to the development of more effective radiation protection standards for occupational exposures on Earth as well as in space.

The development of concepts and implementation plans for a Health Maintenance Facility in the Space Station is underway. This facility will provide both medical care to sick crew members and provisions for maintaining the general health of crews for 90-day periods through the use of exercise, nutrition, and drug therapies.

Gravitational Biology. The goals of the Gravitational Biology program are to use the unique characteristics of space, particularly microgravity, as tools to advance knowledge in the biological sciences; to understand how gravity has shaped life on Earth; and to determine how the space environment affects both plants and animals.

In 1985, various results of ground-based animal studies were confirmed during the data analysis of Spacelab-3, which carried aloft 12 adult and 12 juvenile rats for 7 days. Postflight examination revealed pronounced changes in muscle cells, in certain organs, and especially in bones. Production of interferon, an important immune system chemical and growth hormone was markedly reduced. These findings have implications not only for biological science, but also for other mammals in space, notably humans.

Ground-based animal research provided other significant information that is consistent with observations on humans in flight. Weight-bearing was found to be essential in the activation of bone forming cells. Also, muscle loss in rat hindlimbs during simulated weightlessness caused the remaining muscle to fatigue more readily and to develop an increased sensitivity to hormones that regulate muscle mass.

In 1985, substantial progress was made in delineating the gravity-sensing mechanisms of plants. Starch-containing organelles in certain plant cells (amyloplasts) settle against the cell wall in the direction of gravity. This settling is thought to cause the cell membrane to deform and to institute the redistribution or activation of calcium and the hormone auxin, substances which play a pivotal role in linking gravity detection with cell growth patterns.

Information concerning the fundamental behavior of plants and methods for growing and maintaining them in space contributes directly to the development of a biological regenerative life support system to provide food, water, and a breathable atmsophere for crews on extended space missions.

Planetary Biology. The Planetary Biology program supports investigations which study the conditions necessary for the origin and evolution of life, traces evolutionary paths taken by atoms and molecules that comprise living organisms, and searches for life and life-related molecules beyond Earth.

Among the investigations is a project designed to trace physical and chemical paths of biogenic elements and compounds from their origins in stars to their incorporation in pre-planetary bodies. Four new interstellar organic molecules, including the first interstellar hydrocarbon ring compound, have recently been detected by analysis of laser probe data.

In 1985, researchers found that certain clay minerals showed properties previously thought to be associated only with organic living systems. The ability of those clay minerals to store and release energy, bind and retain biologically important molecules, and catalyze complex organic reactions caused scientists to speculate that clay minerals were important in the origin of life on Earth and may have significantly influenced the rate and direction of chemical evolution.

Work is currently underway to conduct Exobiology experiments on NASA's upcoming Comet Rendezvous and Asteroid Flyby mission which should provide information on the organic chemistry of the early solar system and on the chemistry required for the origin of life on Earth. NASA's Life Sciences program is also supporting the search for intelligent life beyond the solar system. Preparations for the search have already begun. Scientists from various disciplines joined engineers and computer experts to devise the most cost-effective approach to conduct a search for extraterrestrial intelligence. A special prototype device to verify system design was installed and tested at the radio antenna at NASA's Goldstone facility.

Biospherics Research Program. The Biospherics Research program supports research on the dynamics of the Earth's biosphere in order to understand how living and nonliving components of Earth modify each other on a global scale.

To determine what laws govern biogeochemical cyclic processing, research efforts are concentrated in four specific areas: wetlands, along the eastern part of the United States; temperate forests, represented by Sequoia National Park; tropical forests, represented by studies in the Amazon; and global studies concentrated on biogeochemical models. A new effort on remote sensing and public health will evaluate the use of remote sensing technology to predict the spread of disease-bearing insects.

Although the Biospherics Research program is in its infancy, it has the potential to make major contributions toward monitoring and managing Earth's resources. In time, scientists may be able to develop global techniques for effective land use management, increased food and fiber yield and biomass productivity, and the repair of ecosystem damage from natural causes and man-made incursions.

Controlled Ecological Life Support System. Up to the present, all NASA manned space missions have been of short duration, using expendable supplies of air, water, and food. However, for the 90-day missions of the Space Station, it will be advantageous to use available technology to regenerate the air and water supplies. For missions contemplated for the first quarter of the 21st century, of longer duration and at greater distances from Earth, it will also be necessary to regenerate the food supply.

A goal of the Controlled Ecological Life Support System (CELSS) program is to develop the technology needed to make food-regenerating life support systems practical.

The main topics of CELSS research have been techniques for growing higher plants and algae, processes for recycling solid and liquid wastes, and system interactions in biological life support systems. The goal is to achieve a space system which consumes no more than 5 to 6 kilowatts per person and is contained in a volume of approximately 20 cubic meters per person.

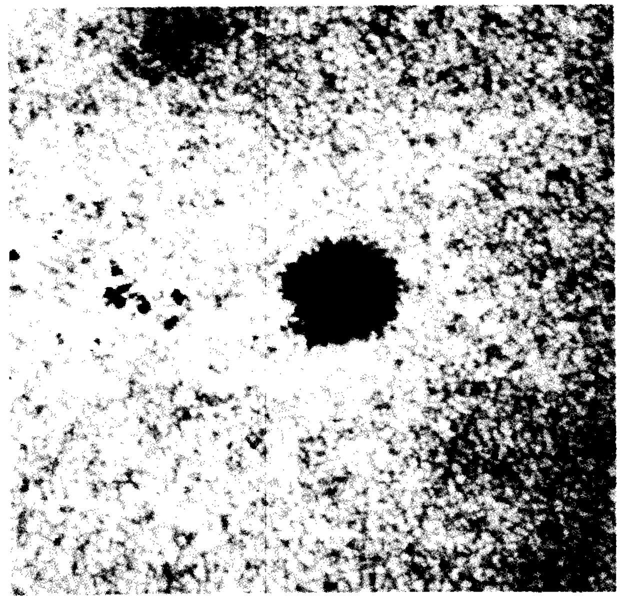
Laboratory results obtained in 1985 show that these specifications can probably be met or exceeded. Energy conversion efficiencies (in terms of usable dietary calories divided by the photosynthetically active light energy needed to produce them) in the 7 to 9 percent range have been obtained for wheat, potatoes, and soybeans; efficiencies approximately twice as high have been measured for two kinds of algae. A demonstration model of CELSS is being constructed at the Kennedy Space Center.

Spacelab Flight Program

Spacelab 2. The launch of Spacelab 2 in July 1985 culminated nearly 10 years of work. This Shuttle mission was the most complex one to date. During the mission, flight verification tests were conducted of Spacelab's igloo-pallet configuration, developed by the European Space Agency; and the Instrument Pointing System was used. Data were obtained in solar physics, plasma physics, x-ray and infrared astronomy, cosmic ray astronomy, life sciences, and technology. The value of the scientist-astronaut and payload specialists was once again demonstrated. The two payload specialists were solar physicists who actively controlled, planned and operated the cluster of solar instruments.

The Solar Optical Universal Polarimeter (SOUP) instrument obtained 6,000 images of the Sun. The smallest visible features on the pictures were 350 kilometers in size. While a few images of such high resolution have been obtained previously, such an extended time coverage from the ground is not possible because of atmospheric turbulence. The solar "movie" obtained by SOUP will be a powerful tool for the study of convection, a basic heat transport mechanism in stellar atmospheres.

The Solar Ultraviolet High Resolution Telescope and Spectrograph obtained a very large number of spectra of the chromosphere, the layer of the solar atmosphere just outside the Sun's visible surface. The main purpose of this investigation was to obtain information on rapidly changing features. Jet-like features, shooting material out at velocities of a few hundred kilometers a second, had been detected previously on short-duration rocket flights but the physical process could not be studied in detail until now. These features may be responsible for heating the base of the solar corona, the extremely hot layer of gas that extends beyond the surface of the Sun.



An image of the Sun taken by the Solar Optical Universal Polarimeter instrument flown on Spacelab 2.

The Coronal Helium Abundance Experiment obtained data on the abundance of helium, the second most plentiful component of the Sun and the universe. Information on the amount of helium is crucial for theories of the solar interior, as well as for cosmological models.

A unique set of active plasma physics experiments was conducted using the orbiter, an electron beam generator, and a small sub-satellite deployed and recovered during the mission.

Scientists have recently begun analyzing the Spacelab 2 data and preliminary results will be reported in 1986.

Spacelab 3. In May 1985, Spacelab 3 successfully completed a seven day microgravity mission in orbit. Exciting results were obtained in materials science, life sciences, fluid mechanics, and atmospheric and astronomical observations.

A vapor transport system and a fluid experiment system were used to grow crystals without the effects of gravity, convection, and circulation which affect their formation on Earth. Initial results indicate significant improvements in the characteristics of crystals for application in the areas of electronics and sensors. Crystals of mercuric iodide

High quality mercuric iodide crystal grown during the Spacelab 3 microgravity mission.

and triglycine sulfate were grown using the Fluid Experiment System/Vapor Crystal Growth System. Analysis of the flight crystals has begun, and preliminary indications are that the crystals are of high quality.

Fluid dynamics experiments resulted in new postulates and unusual effects relative to fluid properties. Containerless processing was demonstrated using acoustical levitation techniques. Key results are expected to influence future Spacelab and Space Station operations in materials handling and processing.

Two of the investigators selected for flight were aboard the Spacelab 3 mission as payload specialists. The benefits of having scientists, both mission and payload specialists, to conduct experiments in a space laboratory were clearly demonstrated. In spite of some difficulties with the animal housing equipment, life sciences experiments were able to measure the effects of microgravity on animals. The results provide an excellent data base with which to compare human responses on future flights. Valuable data on the composition of the atmosphere and aurora were also obtained during the mission.

Spacelab 3 was the first fully operational Spacelab mission with primary emphasis on scientific operations. Important data were acquired, and provided to the investigators, and a science symposium on the results was held in December, 1985.

Japan has entered into an agreement with NASA for a reimbursable Spacelab Shuttle flight (Spacelab-J) in early 1989. Approximatly 45 experiments are planned, primarily in the areas of materials processing and life sciences. A Preliminary Design Review of the Japanese payload was concluded in June 1985, and the Critical Design Review was completed in November 1985. Three Japanese payload specialist candidates were selected, one of which will be chosen for the actual flight. A complementary set of U.S. experiments is being developed for flight on the same mission. The first science working group, with participants from the United States and Japan, met in September 1985 to formulate plans for the mission.

Materials Microgravity Science. Scientific experiments on materials in a microgravity environment were conducted in November 1985 on the second flight of the Materials Experiment Assembly (MEA), which flew as part of the German Spacelab D-1 complement. Experiments included investigations of semi-conductor materials, miscibility gap materials, and containerless processing of glass melts. These experiments complement and extend investigations which were conducted in June 1983 on the first flight of the MEA on the STS-7 Shuttle flight. Data analysis and evaluation of processed specimens are expected to confirm previous results and provide criteria for continuation of these investigations on future MEA flights.

Procurement of the Materials Science Laboratory (MSL) payload carrier for microgravity investigations in the Shuttle cargo bay was completed in May 1985; and the MSL was delivered to the Kennedy Space Center for integration and future flight of the first MSL payload. The MSL payload carrier is designed to use residual space in the orbit cargo bay and to satisfy user needs for accommodations which are compatible with the standard mixed cargo allocation of Shuttle resources (power, data, and thermal control). This design philosophy will greatly enhance flight opportunities for microgravity science investigations in the orbiter. Experiments conducted on the mission in December 1985 used the Electromagnetic Levitator Furnace, the Automatic Directional Solidification Furnace, and the 3-Axis Acoustic Levitator. Investigations were in the areas of: undercooled solidification in quiescent levitated drops, aligned magnetic composites, containerless glass processing, and dynamics of compound drops.

Microgravity Science and Applications. The Microgravity Science and Applications program conducts research into the effect of microgravity on basic physical phenomena and processes. Research is carried out in six disciplines; combustion science, biotechnology, electronic materials, metals and alloys, glasses and ceramics, and fluid dynamics and transport mechanisms. The goal of the program is to quantify the effects imposed by gravity on phenomena and processes and to apply this basic knowledge to specific ground and space-based processes and products.

Research and Analysis. In 1985, the Microgravity Materials Science Laboratory was opened at NASA's Lewis Research Center. It provides easy access and assistance to U.S. industry, academia, and government researchers wishing to conduct materials research on Shuttle flight-type equipment. It has facilities for research in metals and alloys and electronic materials, and will be expanded to additional areas. The laboratory provides characterization and chemical analysis facilities, as well as apparatus for conducting experiments.

Two Centers of Excellence in Bioprocessing and Pharmaceutical Research are in place. One is located at the University City Science Center in Philadelphia, and the other is at the University of Arizona in Tucson.

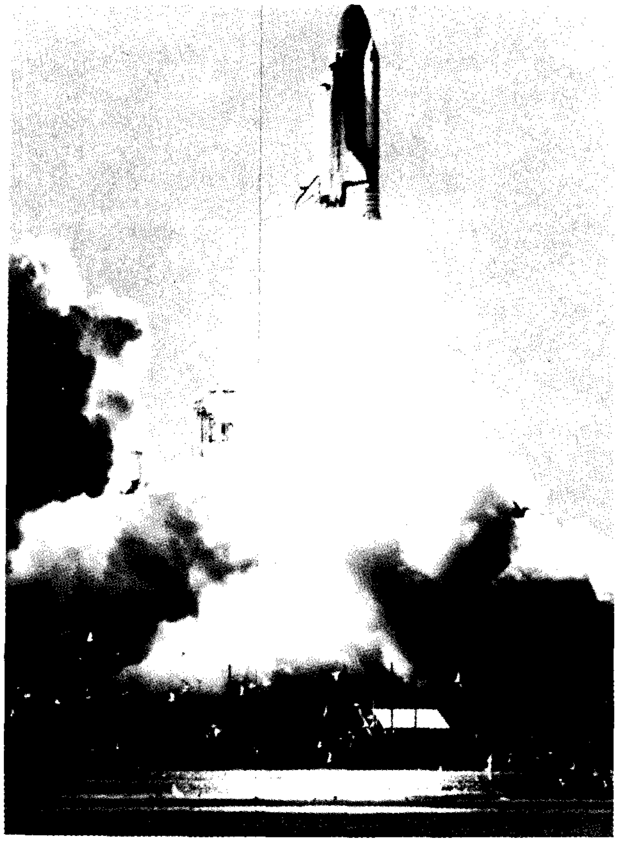
Also in progress is a research program on growing protein crystals in microgravity. The first phase of this program is essentially an engineering proof-of-concept of the hardware and the technique. More controlled scientific research will begin on later Shuttle flights.

Apparatus Development. A number of pieces of experimental apparatus were completed in 1985, including a Three-Axis Acoustic Levitator, an Automatic Directional Solidification Furnace, an Electromagnetic Levitator, and a Solid Surface Combustion Experiment. Work began on the development of an Advanced Automated Directional Solidification Furnace capable of more controlled processing temperatures than earlier versions provided. Work also was started on an experiment, the Specific Heat of Helium through the Lambda Point.

Space Transportation

Space Shuttle Flights

Nine Shuttle flights were launched in 1985. Highlights of these flights include the first public official in space, Senator Garn; the largest crew to date, eight; two dedicated Department of Defense missions; four flights deploying commercial communications satellites; and three Spacelab flights.



The first flight of the year by Space Shuttle Discovery was also the first dedicated Department of Defense mission.

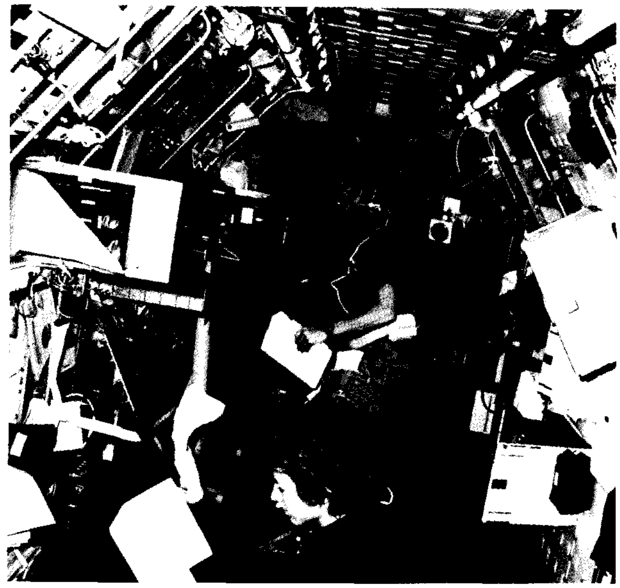
The first flight of the year, on January 24, 1985, was also NASA's first dedicated Department of Defense (DOD) Shuttle mission. The second DOD dedicated mission, October 3, 1985, marked the maiden voyage of Atlantis, the fourth Shuttle orbiter.

As part of its program for launching commercial and foreign payloads, NASA launched several communications satellites into geosynchronous orbits during shared Shuttle flights. They include Telesat-1, Syncom-IV-3, Morelos-A, Arabsat-A, Telstar 3-D, ASC-1, AUSSAT-1, Syncom-IV-4, Morelos-B, Satcom Ku-2, and AUSSAT-2.

In addition to these deployments, the Shuttle and crew salvaged and repaired the Syncom-IV-3 satellite. In April, the crew attempted to activate the satellite after it was deployed from the Shuttle and its boost stage failed to fire. Although the salvage operation went according to plan, the satellite failed to respond and continued to drift in a low Earth orbit. In August, a second Shuttle

169-254 0 - 86 - 2

Crew members aboard flight 51-D take time from their busy full week in space to pose for a photograph. Counter-clockwise from the bottom left are Jeffrey A. Hoffman, mission specialist; Dr. Rhea Seddon, mission specialist; Charles D. Walker, payload specialist; U.S. Senator Jake Garn, payload specialist; S. David Griggs, mission specialist; Karol J. Bobko, mission commander; and Donald E. Williams, pilot.



Astronaut Bonnie J. Dunbar and German payload specialist Reinhard Furrer examine scientific experiments aboard the West German D-1 Spacelab mission.

salvage and repair mission modified the satellite so that it could be activated by the ground. Subsequently, it was boosted into geosynchronous orbit. Although such a repair mission had never before been attempted, confidence was high due to experience from repairing the Solar Maximum Mission satellite in April 1984 and from retrieving the Palapa B-2 and Westar VI satellites in November 1984.

The three Spacelab missions were very successful and provided valuable scientific data to the U.S. and foreign scientific communities. Spacelab 3, the first operational flight of Spacelab, demonstrated capabilities for multidisciplinary research in areas of the life sciences, microgravity processes, and atmospheric observation. The second Spacelab mission, Spacelab 2, flew without the habitable module, but with the Instrument Pointing System used for the precise aiming of telescopes. Both the science aspects and the test of the new Spacelab systems were highly successful. The Spacelab D-1 mission on October 30, 1985, was the first German Spacelab mission. Its crew included one Dutch and two German payload specialists who performed experiments, assisted by NASA's mission specialists. Control of payload operations was conducted from a site near Munich rather than from Houston. All of the Spacelab systems performed flawlessly.

As part of the long-range basic research goal of exploring the space frontier for potential commercial applications in materials processing, the Shuttle also carried research experiments sponsored by the 3M Company during its mid-April and December missions.

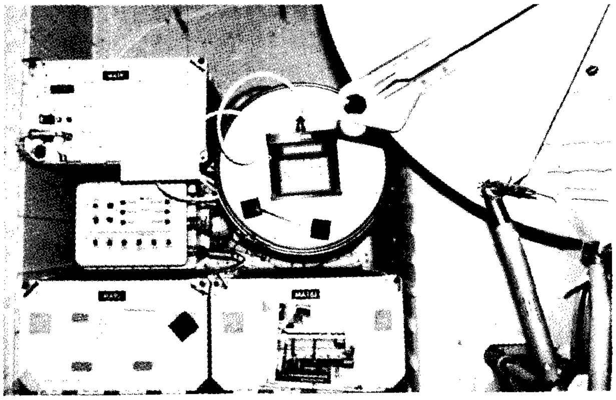
Flight Operations

The Space Transportation System's flight operations include mission planning, crew training, mission control and flight software production.

Improvements to the operations facilities at Johnson Space Center continued, with emphasis on the Shuttle Mission Simulator and the Mission Control Center. Phase 1 of the Simulator Reconfiguration System was completed and utilized in the training for the Shuttle's December flight. Completion of Phase 2 in 1986 will raise training capacity to the equivalent of 18 flights per year. With regard to the Mission Control Center, the first major procurement contract was under negotiation to replace four IBM 370's and one IBM 4341, which are now overloaded, with four machines having considerably greater capacity.

Johnson Space Center awarded a Space Transportation System operations contract which consolidates all or parts of 22 support contracts involving 16 firms. Consolidation will reduce overhead costs, and use of completion form contracting and incentives will reduce costs further. The 2-year contract starts January 1986, and is for approximately 3,600 man-year equivalents.

The eleventh class of astronaut candidates was selected in 1985. Six pilots and seven mission specialists were chosen. Henceforth, NASA will accept applications and maintain a roster of eligibles from which selections will be made as needs arise.



Diffusive Mixing of Organic Solutions (DMOS), a 3M experiment that produced organic crystals in microgravity on Shuttle mission 61-B.

Launch and Landing Operations

Orbiter Atlantis was delivered to the Kennedy Space Center (KSC) for its initial flight. Of the nine Shuttle missions flown in 1985, three were by Challenger, four by Discovery, and two by Atlantis. With additional operational experience, turnaround capability for processing flight hardware has continued to improve. Also, plans and action were initiated to transfer responsibility for orbit logistics to KSC.

Emergency Landing Site

In August 1985, an agreement was signed with the Government of Chile that will allow use of Mataveri Airport, Isla de Pascua (Easter Island), as an emergency landing site for the Space Shuttle. As a provision of the agreement, the runway at Mataveri will be extended to 11,000 feet. The use of Mataveri will be as an emergency landing field only for those launches taking place from the West Coast Shuttle launch and landing facilities at Vandenberg Air Force Base, California.

Orbiter

In 1985, Atlantis completed two missions. The maturity of the orbiter's subsystem is characterized by a decrease in the number of anomalies during its mission. Also, the orbiter flight test vehicle, Columbia, was modified to bring it to an operational configuration. Columbia was returned to KSC where it was processed for its seventh mission scheduled for the following January. During 1985, orbiter improvement programs were continued on the auxiliary power unit, brakes, nosewheel steering, general purpose computer, and inertial measurement unit. These programs will significantly improve the performance of the oribiter.

While the nosewheel steering modification was being incorporated into the fleet, several landings took place at Edwards Air Force Base, California. The modification was checked out on the late-November Shuttle flight for landings at KSC scheduled for the following January. After delivery of Atlantis and Columbia, use of the oribiter assembly facility at Palmdale, California, was essentially discontinued. However, the structural spares program continued on schedule, and the spares will be stored in the Palmdale facility. These structural elements will reduce the down time of an orbiter, and will decrease the delivery time for an additional orbiter.

The procurement of lay-in spares to support the increasing flight rate continued. The usage data accumulated through 24 flights is being used to calibrate the accuracy of previous estimates of out-year requirements. As the data base matures, the ability of the logistics program to support the flight rate will continue to improve.

The Remote Manipulator System (RMS) continues to be a very useful tool and has performed excellently. During 1985, extravehicular activity (EVA) by astronauts also was significant. The first contingency EVA in April, attempted to activate the nonresponsive Syncom-IV-3 satellite by tripping an activation switch. The EVA was successful in installing a "flyswatter" mechanism on the RMS, which then succeeded in tripping the switch. However, the spacecraft could not be activated. In August 1985, a second EVA repaired the multi-million-dollar spacecraft verifying the Shuttle's ability to repair and service oribiting spacecraft. On the last mission in November, another EVA capability was demonstrated, that of assembling space structures. This capability will be of particularly great value during assembly of the Space Station.

Main Engine (SSME)

The Space Shuttle main engines (SSME's) exhibited excellent performance and endurance on all flights in 1985, although one engine was prematurely shut down as a result of instrumentation failure during the Shuttle's July flight. Flight certification extension testing at 104-percent power level was completed, with engines 2010 and 2014 accumulating over 20,000 and 14,000 seconds of total ground test time, respectively. This is equivalent to 38 and 27 Shuttle missions, respectively, since the nominal duration of engine operation during a mission is 520 seconds. The Phase II certification test program, covering improvements in the design of the two high-pressure pumps to increase their operating life and performance margin, was completed. Also, significant im-

Aided by mission specialist James D. van Hoften, Astronaut William F. Fisher repaired the Syncom IV-3 satellite; subsequently, it was boosted into geosynchronous orbit.

provements were realized in the operating life and performance margin of SSME hardware at full power level, 109 percent.

Manufacturing improvements to increase the capacity and capability of flight hardware are continuing. Plant modernization projects, to be completed in 1986, include establishment of a new turbopump fabrication center, and an engine overhaul center, plant rearrangement, machine tool modernization, and improved welding processes.

External Tank

All Space Shuttle external tanks flown in 1985 performed as expected. Ten tanks were manufactured and delivered on or ahead of schedule, and cost savings and production improvements continued to be implemented. Two additional tanks were delivered to the West Coast launch site, making a total of three tanks available at Vandenberg Air Force Base (VAFB). At the end of 1985, fifteen tanks were in various stages of manufacture at the New Orleans, Louisiana, Michoud Assembly Facility. Negotiations should conclude in 1986 on a proposal from Martin Marietta Corporation for a sixty tank "fifth buy."

Solid Rocket Booster

The Shuttle's Solid Rocket Boosters (SRB's) continued to perform as predicted. All boosters were recovered and are being refurbished for reuse. Twenty boosters, or ten flight sets, were delivered in 1985. Development of the Filament Wound Case (FWC) for the SRB progressed with completion of two development static test firings. Qualification and certification of the FWC for flight will be completed in 1986 with the third static test firing and the testing of the structural test article. All of the composite cases for the first flight from VAFB were delivered by July 1, 1985 and stacking of the first FWC SRB began in late November 1985.

Construction of a new SRB assembly and refurbishment facility at KSC was initiated. Activities also continued to incorporate improvements that reduce the time it takes to process the boosters.

Expendable Launch Vehicles

NASA's expendable launch vehicles continued to provide launch support to spacecraft users during the transition of payloads to the Shuttle. Five launches were conducted using expendable launch vehicles, two by Scout for DOD satellites, and three by Atlas Centaur, on a reimbursable basis for INTELSAT.

Upper Stages

The major effort in upper stages is the continued design, development and procurement of the STS/Centaur. Two versions are being developed: the Centaur G prime, which is being funded by NASA, and will be used for NASA's Galileo and Ulysses missions, and the Centaur G, called the Common Centaur, which is being funded jointly by NASA and the DOD. Delivery of hardware and testing are continuing, although on a tight schedule.

NASA is using the Inertial Upper Stage (IUS) developed by the Air Force for boosting spacecraft in the Tracking and Data Relay Satellite System from the Shuttle to geosynchronous orbit.

Commercially developed upper stages also are playing a significant role in the Nation's space activities. The PAM-D and PAM-DII Payload Assist Modules, developed by McDonnell Douglas, performed successfully on 38 missions launched by expendable launch vehicles and the Shuttle since 1980. Twelve of these successes occurred in 1985. Orbital Sciences Corporation (OSC) is developing two upper stages. The Transfer Orbit Stage (TOS), which is expected to be ready for use in the first quarter of 1987, will have a greater capability than that of the PAM stages. It is competing with other upper stages for missions such as the Mars Orbiter. The other OSC stage is the Apogee Maneuvering Stage, whose capability will exceed that of the IUS. In addition, it will be able to be used in concert with the TOS to boost even heavier payloads into geosynchronous orbit.

Tethered Satellite System

The Tethered Satellite System is a cooperative development between NASA and Italy to provide a capability for conducting experiments in the upper atmosphere and ionosphere. It will be capable of deploying and retrieving a tethered satellite up to 100 kilometers below or above the Space Shuttle which will serve as the orbiting base. In 1985, preliminary Design Reviews were conducted on the Italian supplied satellite and the NASA supplied deployer, and hardware manufacture started. The science investigations for the first mission were selected in late 1985. The first use of this system is planned for late 1988.

Spacelab

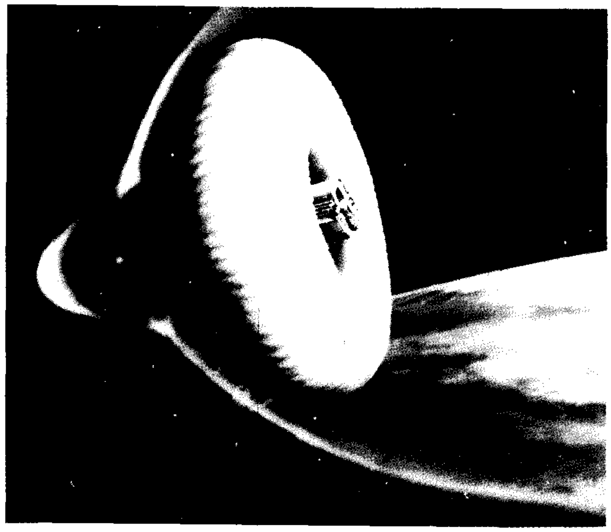
The first operational Spacelab mission (SL-3) took place in April 1985, and the second verification flight (SL-2) in July 1985. SL-3 was a flight of the Spacelab module, while SL-2 was the first flight of the Igloo Pallet Configuration and the Instrument Pointing Subsystem. The first reimbursable Spacelab mission was for West Germany in November 1985. Demonstration flights are planned for the Shuttle Payload of Opportunity carrier known as "Hitchhiker." The new Payload Operations Control Center at Marshall Space Flight Center is nearly complete and will be used first during the Astro-1 mission.

During 1985, the second Instrument Pointing Subsystem, the last major hardware item of NASA's procurement contract with ESA, was delivered. Additional Spacelab hardware is also being procured from Europe, primarily for Spacelab Dedicated Discipline Laboratory flights and an initial hardware reserve. Establishment of a depot maintenance system in Europe also progressed. Development of the Spacelab Pallet System and the Enhanced Pallet System continued. The latter system will be used for Space Technology Experiment Platform missions and Tethered Satellite System missions.

Advanced Planning

System definition studies for an Orbital Maneuvering Vehicle (OMV) were completed, and initiation of system development is planned for mid-1986. The proposal process should be completed in 1986, leading to the availability in 1991 of an OMV capable of performing payload delivery and retrieval from the Shuttle Orbiter. A second OMV will be acquired for the Space Station.

Initial studies of an Orbital Transfer Vehicle (OTV) for basing at the Space Station were completed. Subsequent studies are underway of key concepts such as the use of Earth's atmosphere for braking the OTV when it returns to low orbit. A flight experiment of this concept is being defined.



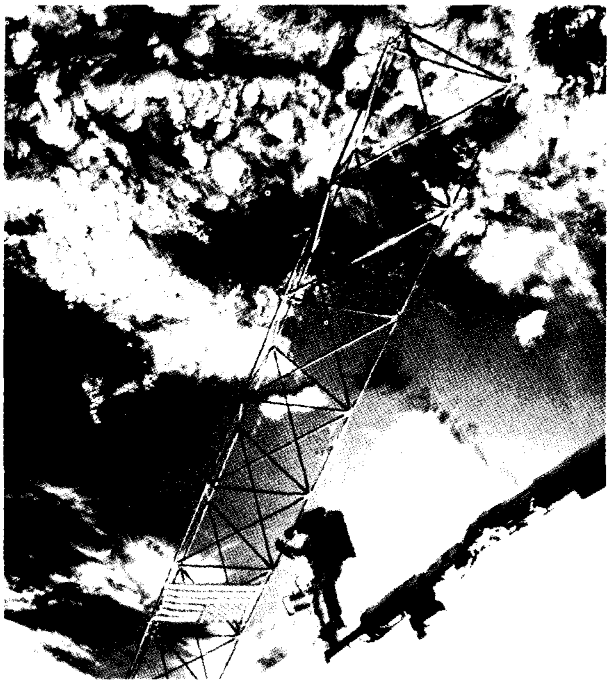
Artist's depiction of the Orbital Transfer Vehicle, to be based at the Space Station, to transport payloads to and from different orbits.

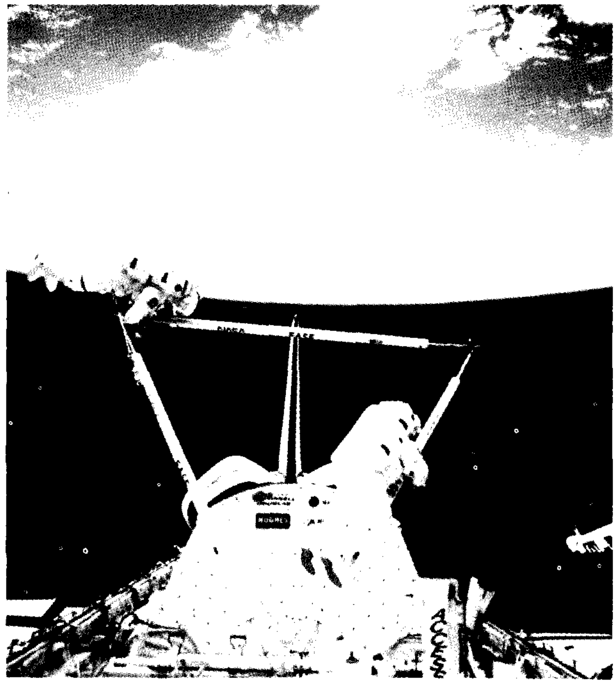
A study and laboratory program to define and evaluate several highly promising applications of tethers in space continued in 1985. Applications being investigated include power generation, orbit raising in the absence of propellants, artificial gravity, and space vehicle constellations.

Under a White House directive to define technology that will lower the costs of and improve launch capabilities in the post-1995 period, examination of future launch vehicles is underway jointly with DOD. NASA is managing two of the system architecture study contracts toward these objectives. Concurrently, preliminary studies were initiated in key technology areas, particularly those related to improvement of booster engines. A study to define a second-generation Shuttle also was initiated.

Development was completed of a significant flight demonstration which then flew on the Shuttle's November mission. The demonstration, which consisted of the Experimental Assembly of Structures in EVA and the Assembly Concept for Construction of Erectable Space Structure, is important to both the Shuttle and the Space Station and, therefore, to the Nation's future in space. It demonstrated the ability of astronauts to assemble elements of a large structure in orbit and measured the productivity of EVA crews.

In 1985, another group of flight demonstrations was initiated, including a proof-of-concept demonstration of a plasma motor/generator, and demonstration of an internal Shuttle communications system using infrared light waves to replace wir-





On the last flight of 1985, STS 61-B, Astronauts Jerry L. Ross and Sherwood C. Spring demonstrate the ease with which large structures can be assembled in space.

ing, and a voice command system to control equipment and reduce current hands-on requirements.

Commercial Use of Space

The focal point for NASA's agency-wide program to encourage commercial space activities is the Office of Commercial Programs (OCP). Established in late 1984, the office has completed its first full year of operation. The primary objectives of the office are to encourage U.S. private sector investment in commercial space ventures and to facilitate commercial application and transfer of existing aeronautics and space technology to the private sector. OCP receives inquiries and proposals related to commercial space activities and also serves as NASA's prime channel of communication and negotiation with private concerns interested in pursuing commercial endeavors in space.

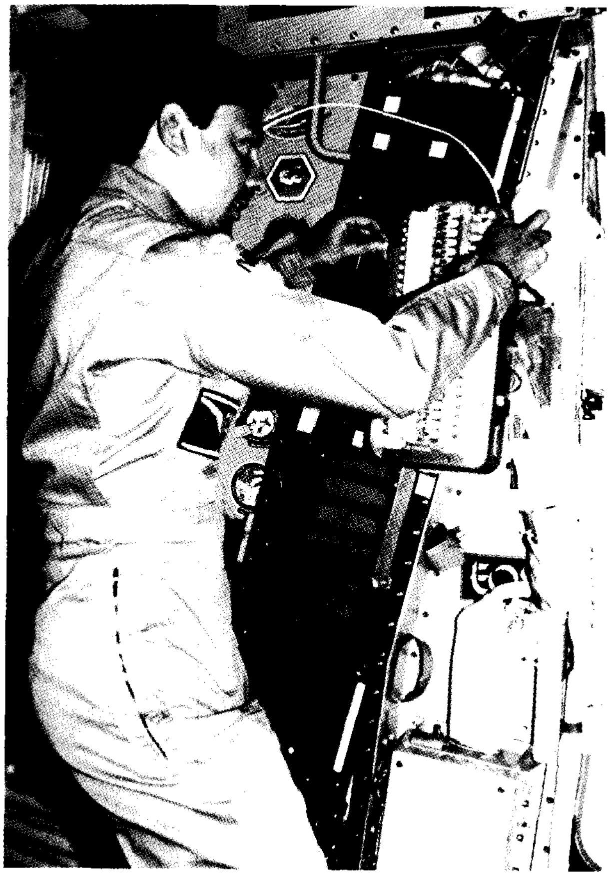
Centers for the Commercial Development of Space

In order to stimulate scientific research considered by the private sector to have potential in the industrial market place, OCP selected and funded five Centers for the Commercial Development of Space. Those chosen and their areas of research concentration are: Battelle Columbus Laboratories – multiphase materials processing; University of Alabama at Birmingham – macromolecular crystallography; University of Alabama at Huntsville – materials processing; Institute for Technology Development in Hancock County, Mississippi – space remote sensing; and Vanderbilt University in Tennessee – metallurgical processing. These centers will perform basic space research activities and, if certain performance criteria are met, will be funded up to five years, after which each center will become self-supporting. Additional centers will be selected in the spring of 1986.

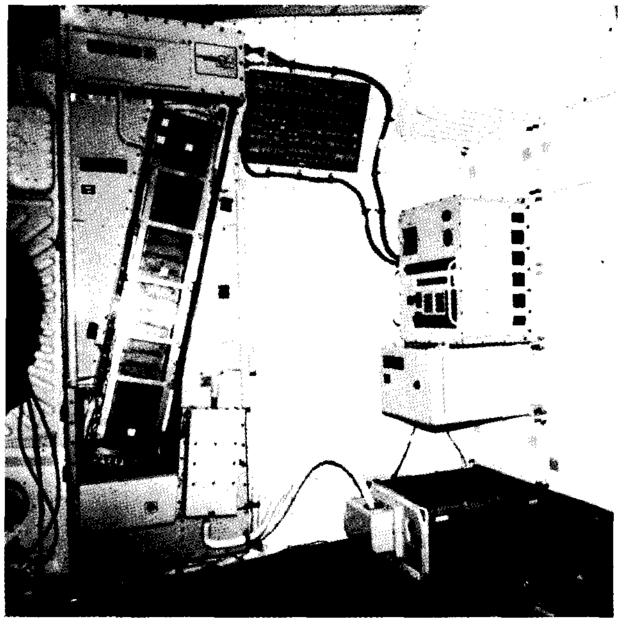
NASA has 24 joint agreements for commercial space ventures in operation. OCP is in the process of evaluating and negotiating an additional 25. In 1985, OCP developed a new type of agreement for doing business with the private sector. This type of agreement, called a Modified Launch Services Agreement (MLSA), features a deferred payment schedule for Shuttle transportation and other related NASA services. In August 1985, OCP developed and negotiated an MLSA with Space Industries, Incorporated, for construction and operation of the first man-tended commercial platform in space.

Federal Research Facilities

Another mechanism to facilitate private sector activities is access to available U.S. Government facilities. OCP will develop facilities with generic



Payload Specialist Charles C. Walker of McDonnell Douglas works with a protein crystal growth experiment aboard a Shuttle flight.



The Continuous Flow Electrophoresis System, developed by McDonnell Douglas, to separate biological materials without the Earthly influences of gravity and convection.

capabilities that will serve many users, but only after the private sector has committed resources for experimental use. During 1985, OCP funded construction of four refrigeration modules, started procurement of an Advanced Automated Directional Solidification Furnace, and began developing a Multiple Experiment Processing Furnace. In addition, OCP partially funded the Microgravity Materials Science Laboratory at NASA's Lewis Research Center. All NASA centers are available to private sector researchers who do not have access to facilities for space-related research.

Technology Utilization Program

The wealth of aeronautics and space technology generated by NASA programs is a valuable national resource having the potential to assist the private sector in developing new products and processes. Translating this potential into reality through information on new applications is accomplished by OCP's Technology Utilization Program. In 1985, significant advances in information dissemination continued through expansion of the independent, university and state-sponsored Industrial Applications Centers (IAC) and through wider circulation of the publication, *NASA Tech Briefs*. NASA has successfully completed arrangements with the Joint Committee on Printing of the U.S. Congress to allow dissemination of *NASA Tech Briefs* as a secondary private sector publication. This arrangement should save the government approximately $400,000 to $500,000 per year because the costs of publication will be covered by commercial advertising. Further, it lifts the 75,000 publication limit imposed by the Office of Management and Budget to restrict publication costs.

In February, the NASA IAC at the University of Southern California entered into an experimental 12-month agreement with the Far West Region of the Federal Laboratory Consortium. The Constorium provides direct access to technical expertise in western laboratories, thus expanding the technology transfer services available to industrial clients. In 1986, OCP plans to negotiate a follow-on agreement to tie NASA IAC's with all federal laboratories. OCP also plans to establish an experimental technology transfer program at NASA's Jet Propulsion Laboratory (JPL). In response to expressions of interest by at least 30 private sector companies, this program will provide private sector access to JPL's scientific and technical expertise. Currently, implementation discussions are taking place with 10 companies.

Applications projects are developed at each of NASA's centers with the support of an applications

The Automatic Implantable Defibrillator, a spinoff from NASA developed technology, can prevent thousands of deaths annually by detecting and automatically correcting erratic heart actions known as arrhythmias.

team. The centers and the team work with both private and public sector sponsors to transfer NASA developed technology to meet a specific need. Examples of results from projects completed in 1985 are: an automatic implantable defibrillator for the heart; Autocuer–a device which electronically assists the deaf or the hard of hearing in lip reading; graphite composites providing lightweight, durable mirrors; klystron technology for television transmission; and an ion beam surface application that prevents rejection by the body of implantable devices. The subjects of projects planned for completion in 1986 are: a programmable implantable medication system; corneal topography; advanced radio for emergency communications; a forest fire detection system; and a burn diagnostic system.

Small Business Innovation Research

In July 1985, the Small Business Innovation Research (SBIR) office was transferred administratively to OCP. This office manages the agency-wide SBIR program initiated in 1983, in response to statutory requirements, and subsequent policy direction from the Small Business Administration. Program objectives are to stimulate technology transfer to, and technology innovation by, small business while also supporting agency mission objectives.

In 1985, 151 of the 1,164 proposals received in response to the 1985 SBIR program solicitation were selected in Phase I contract awards. They averaged approximately $50,000 each. In addition, approximately 60 of the 113 proposals received for Phase II extensions of previous Phase I projects were also selected for contract awards averaging approximately $500,000 each. Since the SBIR program spans all NASA missions and technological objectives, only a few SBIR project awards, to date, relate to potential commercial uses of space. However, greater visibility for this area in the small business community is planned for the future.

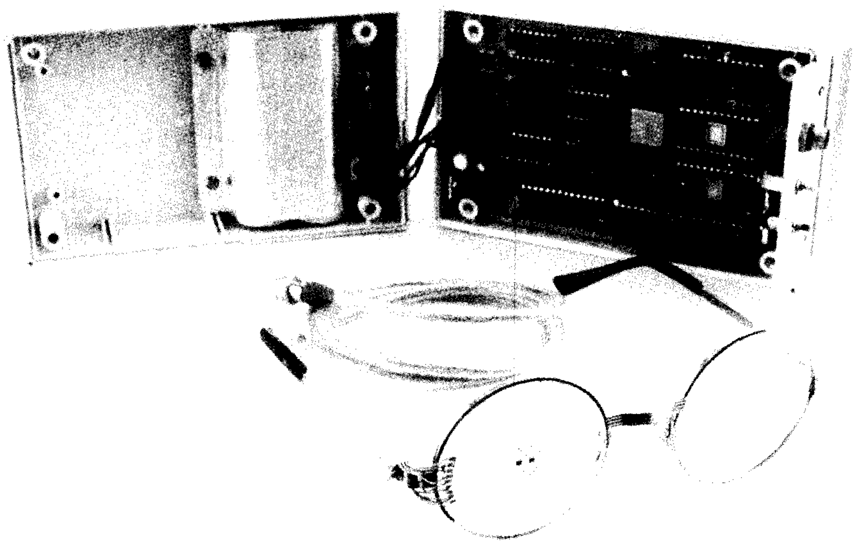
Space Station

NASA's Space Station program gained momentum in 1985 toward fulfilling President Reagan's commitment for the Nation to develop a permanently manned Space Station, with international participation, and to promote private sector investment in space.

The Space Station will be the centerpiece around which a major segment of the U.S. civil space program will be structured. It will be an orbiting scientific laboratory; a test, service, and repair facility for satellites, upper stage rockets, and instruments; an assembly base for large structures; a transportation staging base, a manufacturing site, and an observation platform that will open broad new arenas of opportunity for the scientific, commercial, federal, and international users of space. The Space Station will provide a foundation for leadership in the free world, and for international cooperation in space, for the next decade and beyond.

System Description and Program Status. The Space Station will consist of a manned base, associated co-orbiting and polar orbiting unmanned platforms, and collateral support equipment, such as the Orbital Maneuvering Vehicle. The base will be delivered to and assembled in orbit using the Space Shuttle. It will then be placed in a circular orbit at an altitude of approximately 250 nautical miles and an inclination of 28.5 degrees. Its base station will consist of a truss and servicing structure; habitat, logistics, and laboratory modules; berthing and assembly fixtures; power generating solar arrays; and an advanced remote manipulator system. Its unmanned polar platforms will be tended and serviced by the Space Shuttle.

The Space Station's development and operation will be responsive to the needs of users. Because of

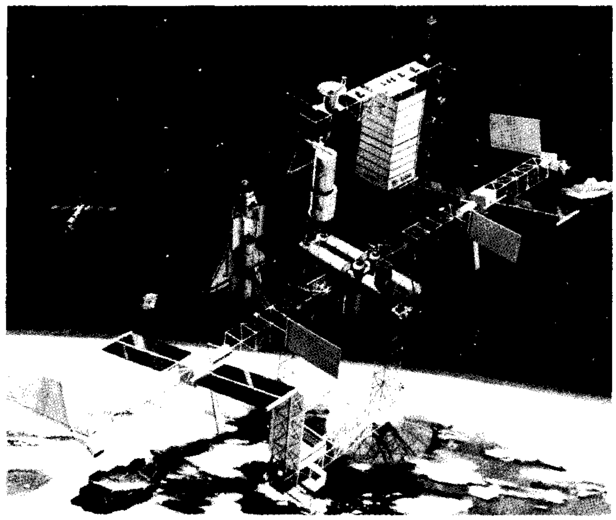


Electronics technology for space missions is used to aid the deaf through the Autocuer, a device attached to special eyeglasses that allows accurate speech perception.

an evolutionary design philosophy, it will be adaptable to emerging requirements. It is supported by an extensive advanced development program initiated in 1985 in cooperation with NASA's Office of Aeronautics and Space Technology. In order to conduct the testing necessary during advanced development, NASA established a series of technology test-beds in 1985. The test-beds, located at various field centers, will quantify and validate the performance of advanced components and subsystems in a ground laboratory environment. Also in 1985, evaluation and testing were initiated in a number of major disciplines such as attitude control and stabilization, power generation and management, thermal control, environmental control and life support, auxiliary propulsion, data management, structures and mechanisms.

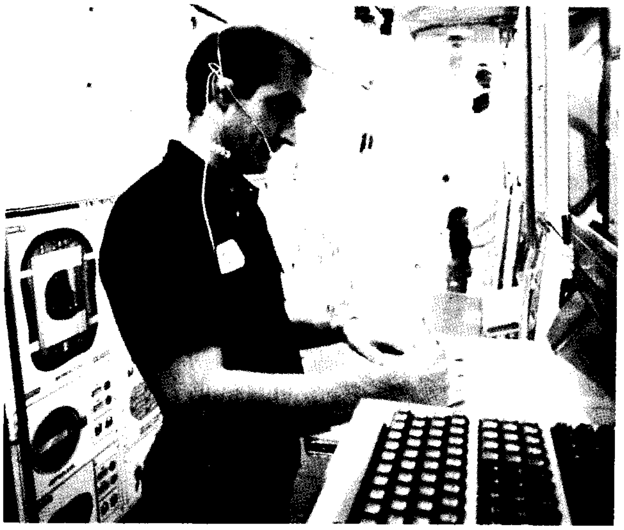
Program Management. The Space Station program plan maintains a strong role for NASA in program management, and provides a framework for competition in industry. The plan is compatible with meaningful international participation, establishes a significant effort in technology development, and provides the opportunity for considerable participation by the user community.

In order to define an optimum configuration for the Space Station, and to minimize technical, schedule, and cost risks, NASA established an extended detailed definition and preliminary design phase for the program. Three years and approximately 10 percent of the program cost will be devoted to detailed studies and preliminary design. To utilize the experience of industry, two prime contractors were selected on a competitive basis for each of four work packages designated for the definition and preliminary design phase. The four work packages are: common module, related systems, and accommodations for the Orbital Maneuvering Vehicle; overall structure and related systems; free-flying platforms and Space Station servicing provisions; and the electrical power system. These contracts were awarded in April 1985, effective for a period of 21 months.



A proposed configuration for the permanently manned Space Station.

Space Station system engineering and integration (SE&I) will be conducted by NASA. In 1985,



A possible configuration for the interior of a working Space Station module under evaluation by NASA scientists and engineers.

an SE&I program office was established at Johnson Space Center, which also coordinates Space Station projects at various NASA centers. Technical panels were formed to review results of trade studies, a master schedule was developed for the definition process, and a data base is being created for exchange of technical information.

Planning is underway for a Technical and Management Information System (TMIS). When operational, TMIS will support communications, coordination and integration, essential for effective program management and control.

A major focus of planning in 1985 was productivity enhancement for the Space Station. This applies to human engineering as well as to the appropriate use of automation and robotics. NASA's Advanced Technology Advisory Committee prepared a key engineering report, mandated by Congress, on the subjects of automation and robotics. The report was submitted to the Senate Appropriations Committee, and a plan to implement the report's recommendations was submitted to the Senate Commerce Committee.

Prior to selection of a baseline configuration for a permanently manned Space Station, NASA will submit a plan to Congress on the Station's proposed man-tended system. The plan will address an approval wherein the permanently manned features are expected to be phased in over three to five years following deployment of the basic Station.

Operations Planning. An operations concept for the Space Station was formulated in 1985, taking into consideration preliminary launch, orbital, and logistics operational requirements, and such objectives as reduced life-cycle costs, and international operations. The operations concept also functioned as input to early phases of Space Station systems design. Two criteria for developing the operations approach were that Station program elements must fulfill affordably the requirements of users, and that the overall system infrastructure and logistics must be affordable to NASA.

As part of this program definition and preliminary design (Phase B) work, contractors studied operational impacts of their design choices. Requirements were established for ground facilities that will allow efficient operations. These requirements will be part of later deliberations on construction of facilities. Congress expressed special interest in NASA's Space Station operations planning and requested a detailed report on the subject, which was delivered.

User Requirements. In 1985, the Space Station Utilization Data Base included over 300 potential payloads from the commercial sector, and technology development, science and applications communities. Besides NASA, user sponsors include the European Space Agency (ESA), Canada, Japan, and the National Oceanic and Atmospheric Administration. Other federal agencies are in the process of formalizing their own requirements.

A large number of users have requested accommodations on the Space Station, and NASA is improving its plan for satisfying those requests. Activities will be in the areas of astronomy, solar physics, materials research and production, Earth observations, solar-terrestrial physics, life and planetary sciences, communications research, technology research and development, and spacecraft servicing.

In the area of co-orbiting platforms, attention has focused on understanding servicing capabilities, and on designing modular platforms that can be customized for different users.

At both operational and research levels, there is significant interest in the use of polar platforms in the areas of solar-terrestrial physics, life sciences, astronomy, and Earth observation. Polar platforms are attractive because they can support many related instruments, can provide operational flexibility because of their anticipated modular design, and can have indefinitely long lifetimes because of their capability for servicing while in orbit.

International Cooperation. In 1985, Space Station agreements with Canada, Japan, and ESA were formalized for Phase B efforts through Memoranda of Understanding. International partners are conducting parallel definition studies of Space Station elements. The Memoranda establish a process to identify elements for preliminary design and, subject to agreement on future phases, for development. ESA is studying pressurized modules, man-tended platforms, and ground support facilities. Canada is studying a module servicing system that includes the Station remote manipulator system. Japan is studying the concept of a multipurpose experiments module. Each of these potential investments could provide significant capabilities to the Space Station and become the foundation for long-term, mutually beneficial activities in the Space Station era.

Space Tracking and Data Systems

NASA's space tracking and data systems continued to provide vital tracking, command, telemetry, and data acquisition support to meet the requirements for NASA, U.S. and international programs. Tracking sites, control centers, and data processing facilities, linked through a global communications system, provided real-time data processing for mission control, orbit, and attitude determination, and routine processing of telemetry data for space missions.

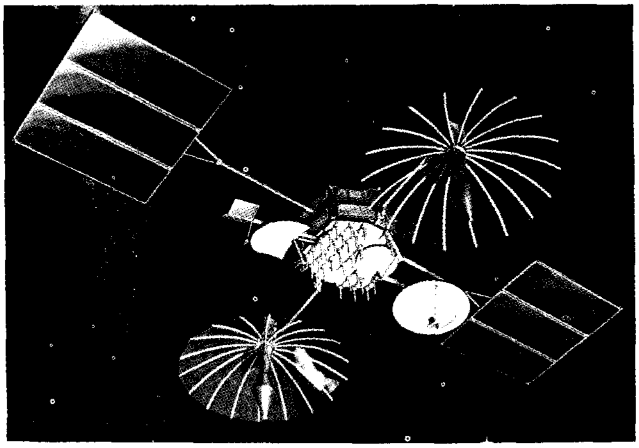
The Space Tracking and Data Systems program is transitioning from a totally ground-based network mode of operation to space-based tracking of low-Earth orbit spacecraft, coupled with tracking and data acquisition of deep space missions by ground stations. The first Tracking and Data Relay Satellite has provided excellent support of several spacecraft missions. With the launches of the next two Tracking and Data Relay Satellites, the required satellite constellation of three in orbit will be completed. The program then will make substantial reductions in the ground-based tracking network that supports near-Earth orbit spacecraft. Most of the network's tracking stations will be closed or transferred to other agencies once the Tracking and Data Relay Satellite System (TDRSS) becomes operational.

The Deep Space Network continues to support some 12 planetary and interplanetary exploration missions and is preparing for an extremely active period in 1986, highlighted by Voyager's encounter with Uranus, and the observation of Comet Halley.

Space Network

The Space Network consists of the Tracking and Data Relay Satellites, the White Sands Ground Terminal, the Network Control Center, the Flight Dynamics Facility, the Simulations Operations Center, the Compatibility Test Vans, and the Bilateration Ranging Transponder System.

The missions that the first Tracking and Data Relay Satellite (TDRS-1) supported in 1985 included those of the Space Shuttle, Landsat, the Earth Radiation Budget Satellite, the Solar Mesospheric Explorer, and the Solar Maximum Mission. The launch of TDRS-2 was deferred due to a problem in the timing circuit of the spacecraft. The problem has been resolved and the launch of TDRS-2 is currently planned for January 1986.



The Tracking and Data Relay Satellite (TDRS-1).

Ground Network

The Ground Network provided tracking and data support for several missions during 1985. It is composed of the Spaceflight Tracking and Data Network, the Deep Space Network, and ground tracking and data acquisition facilities that support the aeronautics, balloon, and sounding rocket programs.

The Ground Network Consolidation program, with facilities located in Spain, Australia and California, was completed on schedule during February 1985. It gives the Deep Space Network support responsibility for spacecraft above the view of the TDRSS, and for older spacecraft that are not compatible with the TDRSS. The Deep Space Network supplied vital tracking and telemetry support for the Soviet-French balloons inflated in the atmosphere of Venus in June 1985 and for the International Cometary Explorer's encounter with Comet Giacobini-Zinner in September 1985.

A major improvement of the Deep Space Network completed at the end of 1985 provided a modern, efficient ground network with new capability to combine signals from several antennae to increase the Network's acquisition of scientific data. This capability is needed to obtain more images from Voyager as it encounters the planet Uranus in January 1986. Currently, the Network is actively supporting many phases of the mission preceding the actual encounter.

Consolidated Ground Network facilities, Canberra, Australia.

Communications and Data Systems

Basic elements of the Communications and Data Systems program form a vital link between the data acquisition stations and the users, including communications, mission control, and data processing. Two major activities under way in the Communications part of the program during 1985 will become operational in 1986. First, a Time Division Multiple Access system is being incorporated as part of the NASA communications network that provides operational support to NASA missions. It will enable more effective use of communications satellite transponders and will improve services throughout the agency. Second is the development and implementation of a Program Support Communications Network to handle the increasing administrative and program management communication needs of NASA and its centers.

In the Data Systems part of the program during 1985, the Spacelab Data Processing Facility processed and delivered on schedule considerable data received from Spacelab-3 in April, Spacelab-2 in July, and the German Spacelab D-1 in November. In addition, development of the Data Capture Facility for the Hubble Space Telescope was completed.

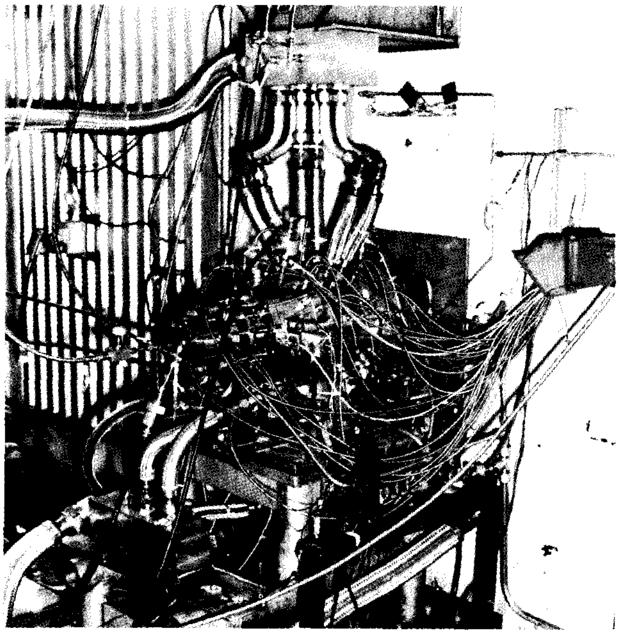
Space Research and Technology

NASA's Space Research and Technology program provides critical, and often unique, elements of the technology base which allow the U.S. to maintain its leadership in space activities. The program focuses on technology for the development of more capable, less costly space transportation systems; large space systems with growth potential such as the Space Station; geosynchronous communication platforms; lunar bases; manned planetary missions; and advanced scientific, Earth observation, and planetary exploration spacecraft. The program includes the disciplinary areas of propulsion, space energy, aerothermodynamics, materials and structures, controls, automation and robotics, human factors, computer sciences and sensors, and data and communication systems, as well as in-space experiments where in situ data are essential. All NASA centers are involved, along with significant industry and university participation.

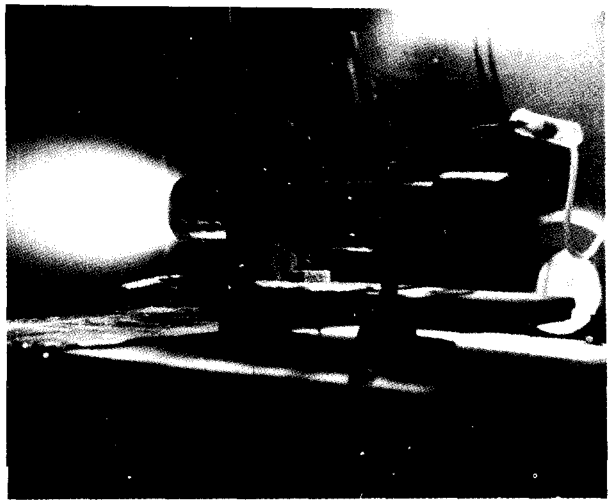
Propulsion. The technology program for advanced propulsion systems for reusable Earth-to-Orbit transportation is focused on combustion and heat transfer; high-performance, long-life turbomachinery; engine critical component monitoring systems; non-intrusive diagnostic sensors; and data analysis systems. Experimental data, combustion, and heat transfer characteristics of high-pressure LOX/hydrocarbon combustion devices are used to update analytical models in order to understand combustion stability and cooling requirements for high-performance design concepts. Thermal models for cryogenic bearings have been developed and are being validated in a NASA test facility which simulates both lateral and axial bearing loads occurring in high-pressure turbomachinery. An isotope bearing-wear detector and a fiber-optic deflectometer, which provide an indication of the wear of critical bearing elements, have been tested in this facility. These diagnostic sensors will be incorporated into Space Shuttle Main Engine turbopumps for evaluation during actual engine operations.

Propulsion studies conducted in conjunction with the analysis of orbit transfer vehicle systems indicate that multiple, high-performance, low-thrust engines with 3,000 to 7,500 pounds of thrust are appropriate and cost effective for a space-based, aeroassisted vehicle. The subcomponent technologies program focuses on appropriately sized high-performance combustors and turbomachinery hardware. Combustion and heat transfer data indicate that lower-thrust designs are compatible with the requirements of engine performance and service lifetime.

The objective of the Auxiliary Propulsion program is significant improvement in the performance of satellite altitude control and orbit changing systems through use of electric-powered thrusters known as arcjets. When adequate power is



A cryogenic bearing test model used to validate bearing characteristics and to predict performance with liquid hydrogen and liquid oxygen.



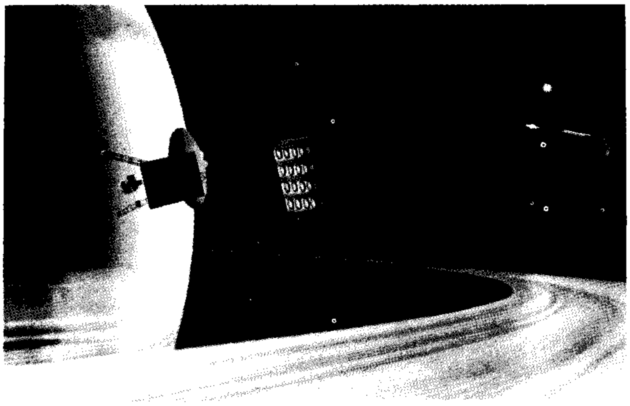
Arcjet thruster operating with ammonia propellant.

available, these thrusters offer more than twice the energy level per pound of fuel that conventional chemical systems provide. Since many satellites are power limited, low-power level capability is important. During 1985, one type of arcjet thruster operated stably at only 500 watts of input power, developing over 400 seconds of specific impulse (31 percent efficiency) with ammonia propellant. Arcjet technology objectives include developing high-temperature materials that are resistant to the electric arc and design concepts for both higher efficiency and longer life. Electric propulsion efforts are closely coordinated with the Air Force; a Memorandum of Agreement emphasizing higher power systems has been signed. It coordinates NASA's arcjet programs with the Air Force's research activities. During 1985, several tests of Air Force 30-kilowatt arcjets were conducted in a NASA laboratory.

When megawatt power is available from nuclear power systems, Magneto Plasma Dynamics (MPD) propulsion technology becomes an attractive option. MPD is capable of developing the highest specific impulse and relatively high thrust. The main technology goal is long life cathodes capable of resisting erosion caused by intense heat (over 3000°F) and electric plasma. During 1985, tests in an MPD simulator at NASA's Jet Propulsion Laboratory demonstrated that there was less erosion at higher power than at low, indicating electron cooling effects. Efforts to develop the technology base for the MPD process are under way at Princeton University.

Space Energy. The Technology Assessment and Advancement Phase (Phase I) of the joint DOE/DOD/NASA Space Nuclear Reactor Power Development Program (SP-100) was completed in 1985. Recommendation that the thermoelectric reactor power system concept be the base-line was approved. A Memorandum of Agreement between DOD, DOE, and NASA for Phase II of the SP-100 Program was executed October 8, 1985. NASA has completed an extensive investigation of future civil space missions that could be aided significantly by nuclear reactor power system technology; they include large manned or man-tended facilities in low Earth orbit, planetary exploration, lunar and planetary bases, large platforms in geosynchronous orbit, and high-performance, in-space transportation systems. In the SP-100 technology advancement effort, significant progress was made in free-piston Stirling energy conversion technology. A 25-kilowatt Stirling demonstration engine, the largest of its kind in the world, has been built and is undergoing performance testing.

Solar cell and solar array technology to improve conversion efficiency, reduce mass and cost, and increase operating life showed significant progress in 1985. Over 20-percent conversion efficiency was demonstrated for gallium-arsenide thick-cell technology. Tests of thin-cell gallium arsenide verified cell efficiency exceeding 14 percent. Research was also initiated for indium-phosphide cells; these self-annealing cells promise an efficiency of 22 percent and offer an order of magnitude increase in radiation resistance. In 1984, an experimental flat-plate solar array flown in space as a Shuttle experiment established 66 watts/kilogram as the current state-of-the-art. A contracted effort was initated to demonstrate advanced designs at 130 watts/kilogram, and



Artist's rendition of SP-100 nuclear-electric propelled spacecraft in the vicinity of Saturn.

concentrator-array designs under investigation promise specific powers up to 300 watts/kilogram.

Technology for solar dynamic systems, which are based on higher receiver temperatures and more efficient conversion systems, offers compactness combined with a potential for increased performance, operational versatility, and longevity. In 1985, a wide-ranging systems study was initiated to identify critical technologies and in-space (zero-gravity) experimentation for specific system component research and technology efforts. Advanced solar dynamic power systems are applicable to both large and small manned and unmanned space systems.

The nickel electrode is currently the life-limiting component of state-of-the-art Individual Pressure Vessel (IPV) nickel-hydrogen power cells cycled at the deep depths of discharge that result from the duty cycles under which they are operated in low Earth orbit. Cycle life performance improved by a factor of four when the electrolyte concentration was reduced from 31 percent to 26 percent; continuing life cycle testing indicates the potential for greater improvement. Significant IPV nickel-hydrogen product improvements for geosynchronous applications have also been verified through testing, and the technology has been transferred to industry.

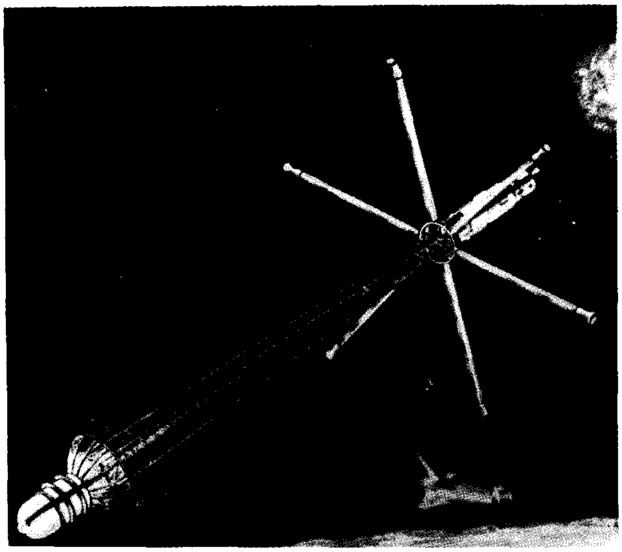
Space power systems generate considerable energy that must be dissipated as waste heat. New thermal management concepts will be required due to the large increases in power needed by planned space missions. Advanced, high-capacity and high-efficiency radiator designs were defined and include heat-pipe, liquid-drop, and liquid-belt approaches. Progress was made in the testing of liquid-drop radiator technology, and a coordinated technology development program with an Air Force field laboratory was established in 1985. Initial liquid-belt radiator design studies were completed, identifying key design issues. These include interface heat exchanger design, containment seal design, and the stowage/deployment system. Deployable heat-pipe radiator configurations were assessed from a design performance standpoint, and critical technology needs were identified for multi-hundred kilowatt power systems like the SP-100 reactor.

Crew life support system technology is focused on regenerative, closed-loop life support systems for long-term needs of lunar or expeditionary manned bases, and for extensive orbital systems operations. Air revitalization, water reclamation, and waste management investigations required for such closed-loop systems have been initiated. Advanced components for these concepts are being tested under simulated conditions.

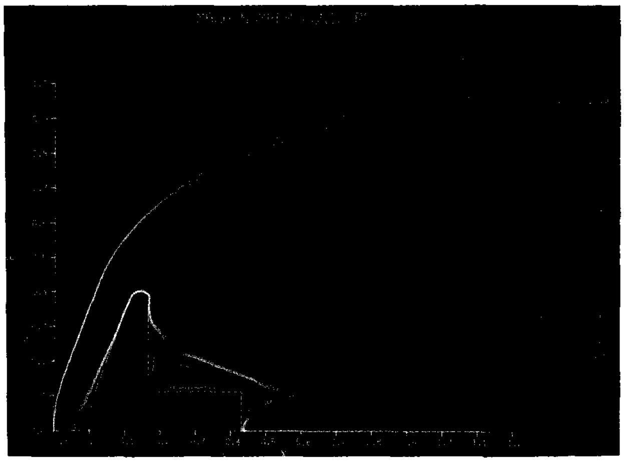
Aerothermodynamics. Progress continues to be made in developing advanced computational methods to characterize the complex flowfields of aeroassisted orbital transfer vehicles. The principal concern for these vehicles is the effect of flow they encounter maneuvering in the Earth's upper atmosphere. Understanding this is critical to the control of the vehicle and to the design of its thermal protection system. In 1985, an analytical code based on a full Navier-Stokes solution to the aerobrake flowfield problem was developed and studied, and indicated weakness in some of the proposed aerobrake designs.

The Orbital Experiments program developed the research-quality instrumentation flown on Columbia and Challenger Shuttle flights. This instrumentation obtained flight data that is being compared to wind-tunnel and analytical data on entry performance. Three instrumentation systems developed in the program were installed on the Shuttle Columbia in 1985: Shuttle Infrared Leeside Temperature Sensor, Upper Atmosphere Mass Spectrometer, and Shuttle Energy Air Data System. They are planned for a minimum of six flights. The Leeside Temperature Sensor will obtain thermal maps of the orbiters' top surfaces, providing data not available through analytical or experimental means. The Mass Spectrometer will provide in situ air environment data, allowing characterization of orbiter high-altitude performance, and the Air Data System will provide high quality, low altitute air and vehicle data. Data from these instruments will contribute significantly to the validation of the aerothermodynamic data base and support the design and development of future space transportation systems.

The first flight in the Shuttle of an advanced autopilot system occurred in 1985. This system can select an optimum control strategy for a given activity, that accounts for thruster or sensor failure. Subsequent flights will investigate the application



An innovative concept for a liquid-droplet heat rejection system.



Computational fluid dynamics solution for an aeroassisted Orbital Transfer Vehicle concept.

of this technology to control docking and berthing, proximity operations, rendezvous, and formation flight.

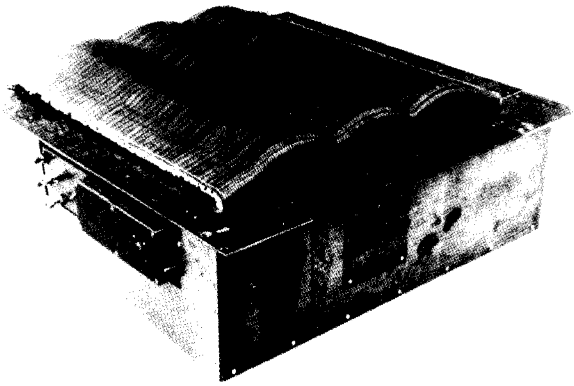
Materials and Structures. In 1985, significant advancements were made in the high-performance thermal protection system (TPS) for advanced space transportation systems. Silica and silicon carbide (Nicalon) fibers were woven in three-dimensional fabrics for the high-temperature TPS applications required by the Orbital Transfer and advanced Earth-to-Orbit vehicles. This technology will provide lightweight, high-strength, reusable TPS structural concepts. By predicting the distortion and temperature distribution of a large, superalloy metallic TPS panel, subjected to 1800°F temperatures in an 8-Foot High Temperature Tunnel test, a major accomplishment in analytical capability was demonstrated. A 3-dimensional integrated thermal, structural and flow analysis was conducted; and the results were correlated with the results of the test.

Significant research efforts are underway to develop structral and insulation concepts for the cryogenic propellants tanks in flight vehicles. This research has potential for significantly reducing the vehicles' weight. Cryogenic foam insulation has demonstrated that it can withstand repeated thermal cycling of $\pm 400°F$. A 50 percent weight reduction over that of conventional foam material systems is possible.

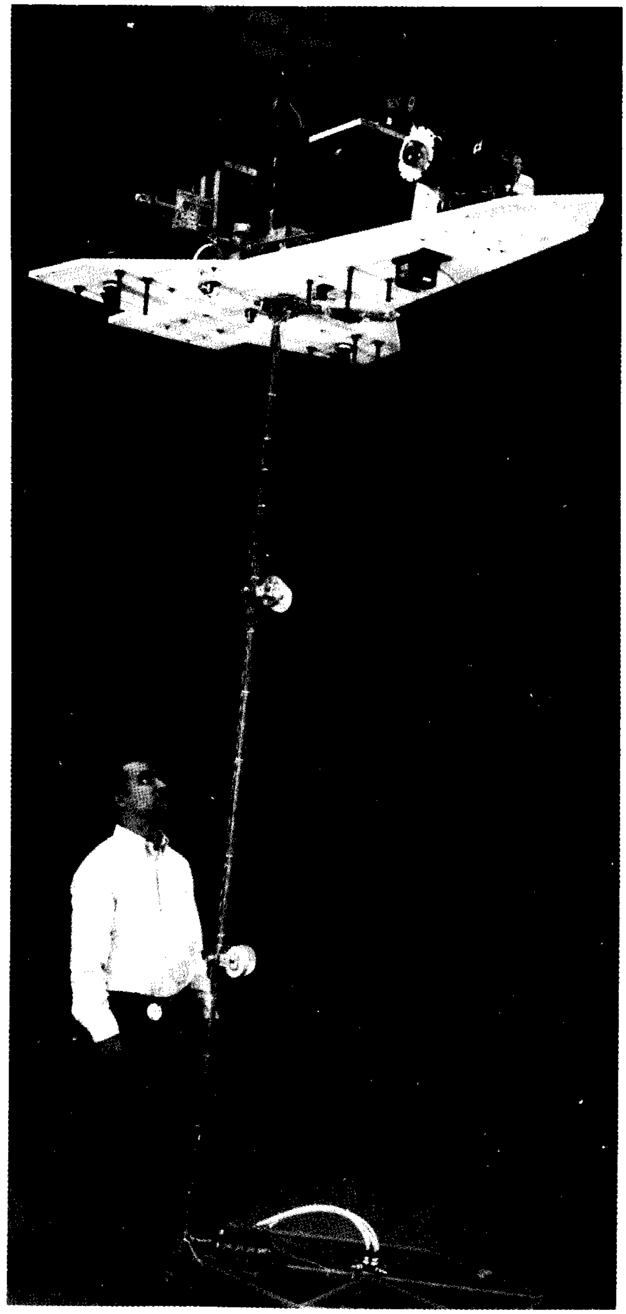
Advances in space structures and construction techniques were made in support of NASA's Space Station program. The ACCESS/EASE in-space construction experiment was conducted as part of the STS-61B Shuttle flight in November 1985. To demonstrate assembly methods, and maintenance and repair concepts, the Shuttle flight crew assembled and disassembled a 45-foot-long triagular truss from individual structural elements and joints stored in the Shuttle cargo bay. A 12-foot tetrahedral pyramid was also assembled in order to provide data on human learning and productivity during in-space structural assembly. It was the first demonstration of in-space construction and repair methods. In preparation for this in-space experiment, Earth-based zero gravity simulation tests, using KC-135 aircraft and the underwater neutral buoyancy facility, were completed.

Development continues of analytic tools and test methods for a better understanding of the dynamics of flexible structures. Deployment dynamics involving nonlinear, large motions were simulated, and the simulation method will be applied to the evaluation of various large, flexible, space structural concepts.

Controls and Guidance. Research has focused on control of large, flexible space systems for application on the Space Station, large antennas, or large, segmented astrophysics telescopes. During 1985, control experiments were conducted for later validation in the Control of Flexible Structures flight experiment. The flight experiment hardware consists of an instrumented, highly flexible, 60-meter beam deployed from the Shuttle. The submillimeter ranging and lateral displacement capability of the Spatial, High Accuracy, Position-Encoding Sensor (SHAPE) was demonstrated for a single point on a large space structure. Plans for a multi-point demonstration have been initiated. The Spacecraft Control Laboratory Experiment (SCOLE) program, to develop control algorithms and control methodologies for large slewed spacecraft, was responsible for a workshop in



Weaving of silica and nicalon fibers to provide lightweight, reusable thermal protection system for Orbital Transfer Vehicles.



The Spacecraft Control Laboratory Experiment (SCOLE)–An important tool in the research of large, flexible structures such as space antennas, Space Station, and reflector telescopes.

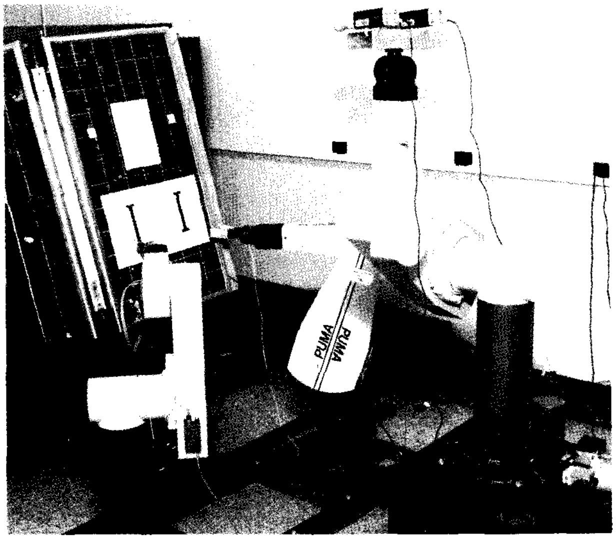
which representatives from eight universities participated, contributing several unique and innovative approaches. The SCOLE test apparatus, which resembles a large offset antenna attached to a model of the Shuttle, will be used to validate control-technique approaches. Initial characterization tests were completed. In ground tests conducted in NASA's 20-meter, vertical, Voyager-mast test facility, the addition of active controls at the mast's base yielded an order of magnitude improvement for damping disturbances. This result gives preliminary verification to the feasibility of flying on the Shuttle and Space Station long, slender, precisely pointed systems, such as the Pinhole Occulter Experiment.

A comprehensive technology plan has been completed for the advanced navigation and control system needed by an Orbital Transfer Vehicle using the Earth's atmosphere to slow its return to low-Earth orbit. This plan has been expanded to include the needs of advanced Earth-to-Orbit vehicles.

A test of a highly accurate guidance sensor called the Fiber Optic Rotation Sensor was completed. When fully developed, this sensor will be more accurate and more stable than existing sensors.

Also completed was the design of a real-time, distributed, fault-tolerant control system called the Advanced Information Processing System. Fabrication of a prototype of the critical element, the data processor, was initiated.

Automation and Robotics. During 1985, several technology efforts were combined into an Automation and Robotics Program. This was done in response to Congressional interest in Space Station, and to reduce costs and increase performance of future missions. The program will develop and demonstrate technology applicable not only to Space Station, but also to potential spacecraft such as the Orbital Maneuvering Vehicle, the Orbital Transfer Vehicle, the Mobile Remote Manipulator System, and the Mars Rover. The program's two foci are telerobotics, which will develop technology to evolve teleoperation through supervisory control of in-orbit robots, and system autonomy, which will develop technology to reduce the need for ground control crews through the use of artificial intelligence. Each of the foci will have a series of



Telerobotics demonstrator designed to be a world-class test-bed for integrating and evaluating state-of-the-art technology for supervisory control of in-orbit robots.

demonstrations to show evolving capabilities. The research program is divided into five technology areas: sensing and perception, planning and execution, operator interface, control mechanization, and system architecture and integration.

Advanced automation techniques, such as expert systems, will increase substantially the productivity of Space Station crews, while ensuring that potentially dangerous systems failures are quickly identified and reversed. To test the concept, an expert system for ground fueling the Shuttle orbiter was constructed in 1985. Such a system will allow Space Station crews to refuel satellites and Orbital Maneuvering Vehicles with greater safety and efficiency.

To reduce the time-consuming and expensive process of planning mission schedules, an expert system called PLAN-IT has been developed at JPL. This system develops schedules for efficient utilization of resources, and identifies and indicates options for resolving conflicting resource requirements. PLAN-IT was developed to satisfy the need for rapid and effective rescheduling of planetary spacecraft activities, and the success of this system has resulted in its application to the scheduling of the Deep Space Network.

To meet the need of autonomous robots for extensive vision capabilities, a Programmable Image Feature Extractor, using Very Large Scale Integrated circuit technology has been developed. It includes feature tracking, motion stereo, and stereo matching, and will process visual information in real time for intelligent robot systems.

Human Factors. Since current suits for Space Shuttle extravehicular activity (EVA) will not meet the requirements of routine Space Station EVA operations, a new suit is being designed and tested at NASA's Ames Research Center. Two Hard Space Suit Demonstrators completed in late 1985 will increase EVA crew productivity by eliminating the need for lengthy pre-breathing, while providing excellent mobility and dexterity, and reducing maintenance requirements.

Because visual monitoring of remote operations will be a vital element of Space Station activities, an ultra-wide field-of-view, helmet-mounted display was designed in 1985. This device is a major breakthrough in engineering design because of its high capacity and very low weight, power, consumption and cost. Because the advanced spatial display makes the remote scene appear to surround the wearer, the user experiences visual "telepresence."

Advanced aerospace vehicles will require cockpit displays that are more advanced than the small cathode ray tubes and electro-mechanical displays in the latest transport aircraft. NASA's Ames Research Center leads the Nation in quantitative design of spatial information and pictorial displays through an extensive program of experimentation. Studies conducted in 1985 showed that use of new classes of displays can decrease reaction time and increase accuracy in assessing tactical situations and vehicle control.

Computer Science. Spectacular growth in the volume of space science data has begun to strain information processing resources. Distribution and analysis of massive amounts of data will require major improvements in the cost-performance ratio of telecommunications. Through a grant to Stanford University's Center for Aeronautics and Space Information Sciences, research is underway to implement a new, low-cost satellite network that will allow university scientists to access directly experiment payloads on the Space Station. The first link in the network connects Goddard Space Flight Center to Stanford. After testing, the link will be used to conduct an experiment with a future Shuttle/Spacelab mission.

Another approach has been developed for accommodating the volume and complexity of space science data. A knowledge-based expert system serves as the basis for a hyperspectral analyzer. The expert system approach to analysis and interpretation of imaging spectrometer data has application in such remote sensing disciplines as geology, geobotany, agriculture and forestry. The amount of spectral data produced by imaging spectrometer instruments (128 to 246 spectral channels per pixel) is overwhelming, and presents a significant challenge to traditional image-processing and analysis methods. The development of knowledge-based expert system methods to cope with the data will greatly enhance the ability of the science investigator to extract useful information from imaging spectrometer instrument systems. This task requires development of an efficient expert system design tool for use in a common programming language, new knowledge representation schemes which allow efficient coupling of symbolic and numerical computation, and development of a specific knowledge base for spectral interpretation in a remote sensing geology context.

Accomplishments in 1985 include design and implementation of a portable expert system tool called Simple Tool for Automated Reasoning (STAR), design and implementation of a knowledge representation scheme based on semantic network concepts, implementation of a prototype expert system using STAR for carrying out imaging spectrometer analysis in a geology context, and utilization of the prototype expert system by remote sensing geology "experts" to build interactively the required knowledge base for sophisticated interpretation problems.

Sensors. The use of charge coupled devices (CCD's) has resulted in a breakthrough for ultraviolet astronomy. Through detailed investigation of the short wavelength response and performance potential of CCD's as detectors, instability of the detector efficiency can be overcome by "backside charging." This induces a phenomenon called pinning, which results in collection of all photo-generated electrons. Direct methods to control pinning provide a basis for the design of instruments that are more capable in the extended spectrum. Backside charging of sensor CCD's has already been applied to the Planetary Camera of the Space Telescope.

Data Systems. The Advanced Digital Synthetic Aperture Radar Processor is under development to demonstrate technology that can meet data processing requirements of missions in the late 1980's. An engineering model under construction will demonstrate this capability in 1986 using existing flight data from the Shuttle Imaging Radar.

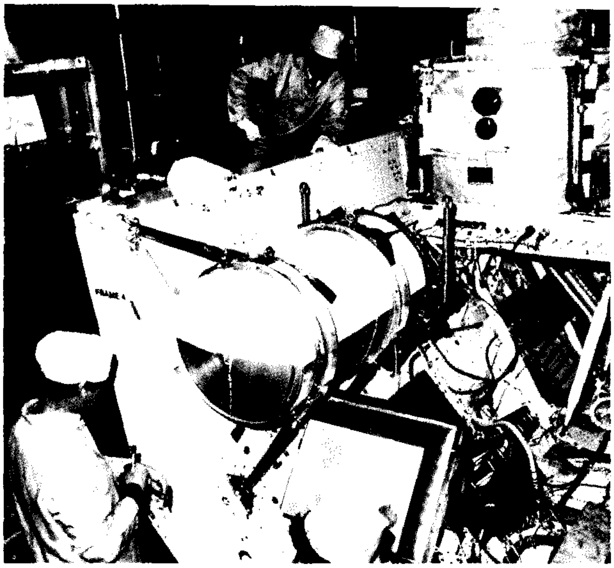
Fiber optics data communications provide the benefits of high speed and insensitivity to elecromagnetic interference. A brassboard, 100-megabit per second, fiber optics data bus called STAR*BUS was delivered in October 1985. STAR*BUS will demonstrate the space technology readiness of fiber optics and will highlight the unique features of star coupler and access protocols. The system has demonstrated the expected 100-megabit performance through a 32-by-32 star coupler. It will be incorporated into the Space Station Focuses Technology Program for use in the Data Management System Testbed.

Communication Systems. The use of a single-aperature/multiple-beam antenna with very low sidelobes was successfully demonstrated. This kind of antenna will provide excellent ground coverage and frequency reuse in mobile satellite applications, without using multiple apertures. An 8-beam overlapping cluster feed was developed and tested. The test used the deployable hoop-column reflector antenna, which also is under development. Preliminary results indicate that contiguous non-interfering beams are possible with single aperture reflector antennas.

A study of advanced communication satellite requirements conducted by NASA's Lewis Research Center determined that a traveling wave tube in the 60-gigahertz range could be required for effective intersatellite links. To meet this need, two coupled cavity tubes to cover the frequency range of 59 to 64 gigahertz were developed. These tubes provide over 100 watts of power. This technology breakthrough allows very high data rate intersatellite communication in this important frequency range. Potential applications include the next generation NASA Tracking and Data Relay Satellite and commercial satellite communications.

In-Space Experiments. Use of the Shuttle to advance space technology continued in 1985 with the conduct of several significant in-space experiments. In addition to those described above, two are of special interest to the scientific community: the Drop Dynamics and Superfluid Helium experiments. The Drop Dynamics experiment was flown on Spacelab 3, which was launched on April 29, 1985. It involved an experiment module which investigted the dynamics of rotating and oscillating fluid drops in very low gravity. A set of fundamental experiments were performed by the payload specialist, who was also the module designer and the Principal Investigator. The highly successful experiment verified that this new facility can manipulate drops acoustically, test theoretical predictions of drop behavior, and observe new phenomena for further investigation. The information gained from this experiment, and from those on subsequent flights, will have practical applications in the development of containerless processing techniques and in the refinement of industrial processes in metallurgy and chemical engineering.

The Superfluid Helium experiment was flown on Spacelab 2, which was launched on July 29, 1985. The objective of this experiment was to investigate the behavior of liquid helium at temperatures below 2.2° Kelvin, when helium is in the superfluid state. In this state helium exhibits several unique properties: its thermal superconductivity is 1,000 times that of copper, and its viscosity is a thousandth that of water. Exact behavioral characteristics in the long-duration space environment are difficult to predict. This experiment has



The Superfluid Helium experiment flown on Spacelab 2 to investigate superfluid cryogenic properties in zero-gravity.

provided improved understanding of the fluid and thermal properties of superfluid helium. Future applications of superfluid helium technology will include the measurement of critical point phenomena and the cooling of telescope sensors, optics and baffles for far infrared astronomy, superconductive devices, gyroscopes, and gravitational wave detectors.

Aeronautics Research and Technology

The United States has long been the world's leader in aeronautics research and technology. It is crucial to retain this leadership, so important to national defense, the economy, and the U.S. international trade balance. While the United States still maintains a broad base of technological advantage, the margin of advantage has narrowed dramatically in recent years. Recognizing that further erosion of the U.S. competitive position can be ill-afforded, the White House Office of Science and Technology Policy (OSTP) issued a report entitled "National Aeronautical R&D Goals, Technology for America's Future." The report was prepared last year by the Aeronautical Policy Review Committee, a group of individuals in government, industry, and academia assembled by the OSTP Director and Science Advisor to the President. The report recommends specific goals for aeronautical research and development to insure continued U.S. leadership well into the next century. Moreover, in order to revitalize America's competitive position, it recommends an intensified research and development program concentrated on certain "high payoff" technologies that offer dramatic new aeronautical systems. Investing in NASA's aeronautical research and technology program is the best way to develop the technology base so necessary to maintain U.S. leadership in aeronautics.

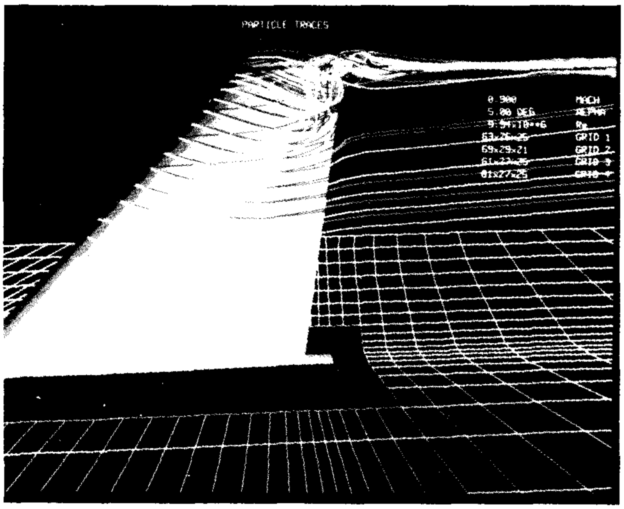
NASA's program is derived from technological disciplines, and spans the flight spectrum from hovering to hypersonic aircraft. Wind tunnels, supercomputers, simulators, and experimental flight vehicles are examples of research tools NASA uses to meet today's challenges and to design tomorrow's aircraft. In both disciplinary research and technology and systems research, NASA strongly supports military and civil aircraft technologies.

Disciplinary R&T

NASA's disciplinary aeronautical research activities provide the technological base for new and innovative ideas necessary for future advances. The research seeks to improve understanding of basic physical phenomena and to develop new concepts in fluid and thermal physics, materials and structures, propulsion, controls and guidance, human factors, and information sciences.

Fluid and Thermal Physics. The aerodynamics program provides the computational methods and experimental data base required to develop advanced aerodynamic concepts and configurations for future civil and military aircraft. Computational Fluid Dynamics (CFD) is emerging as an essential and powerful tool for improved understanding of both external (aircraft) and internal (propulsion system) flow physics. The Numerical Aerodynamic Simulation System (NAS), which will provide the most advanced computational systems in the world for solution of CFD problems, is under development at NASA's Ames Research Center. The NAS system configuration was checked out last year using a Cray XMP supercomputer. The system's Cray 2 supercomputer has been delivered and is being installed with plans for the initial operating configuration in 1986. The extended operating capability will be in place in 1987. In addition to its important advantages in aircraft design, NAS will further benefit U.S. science and industry as a national facility for research in other areas such as non-aerospace structures, materials, weather, and chemistry.

The flow of fluid through turbomachines presents another tough challenge for CFD, and understanding this flow is essential for optimizing turbomachinery design. Computer codes with computer-generated imagery for airflow around internal airfoils were developed to illustrate and



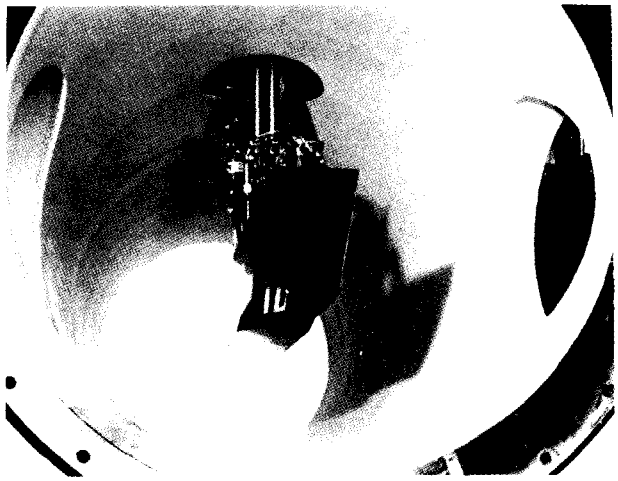
Computational Fluid Dynamics – On external flow applications, NASA has computed the flow around the F-16 wing, and is using the results as a reference bench mark for code verification.

facilitate an understanding of complex flow physics.

Reducing the viscous drag caused by skin friction is a key objective in aerodynamic research, since it accounts for about half of the total drag of an aircraft. Laminar flow control is one technique used to reduce drag. It is a means of controlling the layer of air next to the skin of an airplane, keeping it smooth (laminar). NASA flight tests have begun with a Jetstar aircraft in airline-type service to investigate the effectiveness, practicality, and reliability of a laminar flow control technique. This technique employs suction near the wing leading edge to maintain laminar flow over much of the wing. The system has operated satisfactorily under varying flight conditions.

A new NASA technique uses liquid crystal coatings to determine if laminar flow exists over an airfoil for both wind tunnel and flight tests. The technique overcomes limitations of previous techniques, providing reversible, instantaneous (in real time) visualization of boundary layer transition throughout virtually the complete altitude and speed range of subsonic aircraft. This technique also has application to supersonic laminar flow.

Materials and Structures. Research in these areas provides the foundation for advances in new and improved materials, structural concepts, and analytical methods. NASA has conducted considerable research in secondary structures made of composite materials that are generally lighter, yet stronger, than metals. In June 1985, an Air Force KC-10 aircraft was flown with a NASA-developed vertical stabilizer designed and fabricated with graphite/epoxy composites. FAA certification of this component is expected in 1986, which will be a



Model of a scramjet that has been tested in a wind tunnel at NASA's Langley Research Center.

successful conclusion for the NASA Transport Composite Technology program.

Concepts and advanced analytical technologies for lightweight structures are key areas for transatmospheric and supersonic cruise aircraft. One promising concept under investigation is the use of load-carrying honeycomb panels of high-temperature superalloys. During the past year, a 20-panel array of superalloy honeycomb material was tested, under hypersonic conditions, at NASA's Langley Research Center's High Temperature Tunnel. Concurrent with this test, a comprehensive analysis of fluid flow over the panel accurately predicted vortex-induced and impingement-heating effects leading to local hot spots and thermal bowing. A complex, curved test panel of superalloy honeycomb has been fabricated and will be tested.

Propulsion. Current research encompasses a wide range of technologies that promise more effective propulsion research tools, engine components, and systems capabilities. Consistent with its goal to develop transatmospheric capability, NASA has an active program in propulsion systems for hypersonic cruise. Self-acceleration of the aircraft from takeoff to hypersonic cruise speeds requires the use of dual or hybrid engines. One dual engine concept studied is the over/under engine installation. In this concept, a turbojet is used for takeoff and acceleration to supersonic speed and then a scramjet begins operation. As the performance of the turbojet decreases with higher flight speed, the performance of the scramjet increases. Internal contours of an efficient, variable geometry inlet capable of partitioning the incoming air between the two engines have been designed. Wind tunnel tests have verified that a scramjet can produce sufficient net thrust to sustain a large vehicle at hypersonic speeds.

Small turbine engines are very important to many ground applications, and to many types of aircraft, including general aviation, commuters, helicopters, and cruise missiles. Current efficiencies of small engines are 8 to 10 percent less than those of large engines. Axial flow compressors of the types used in large gas turbines exhibit sizable efficiency losses at smaller sizes. These losses can be reduced by substituting centrifugal compressors. However, centrifugal compressor passages involve much more complex phenomena. In 1985, centrifugal compressors were evaluated analytically and experimentally to determine the effects of scale on compressor performance. The results indicate that centrifugal compressors can be designed and built to approach the excellence of the Energy Efficient Engine axial flow compressor.

Propulsion instrumentation is an important enabling technology for fundamental propulsion research. An advanced optical measurement system was demonstrated that makes possible the non-instrusive measurement of turbomachinery flow fields for an operating engine. Through the understanding of turbomachinery secondary flow fields in small passages, advanced analytical flow codes can be developed, and validated for full engine operation.

Controls and Guidance. Research over the past several years has built a strong technology base for flight controls employing advanced digital electronics, as opposed to mechanical systems, and for systems of integrated flight and propulsion controls that offer greater aircraft efficiency, effectiveness, and safety. As part of its Advanced Transport Operating Systems, NASA flight tested a total energy-control system concept on its Transport System Research Vehicle B-737 aircraft. The system incorporated a full-time autothrottle which controlled the total energy of the aircraft and used the elevator to distribute the energy between speed and flight path. The system has significantly reduced throttle activity and may find early application in new or derivative U.S. transport aircraft.

Future aircraft with highly sophisticated systems will have failure modes that will make it difficult for the pilot to recognize and take corrective action. Such failures may lead to unanticipated sequences of events from which the pilot cannot recover intuitively. Controls that can restructure themselves would enable a system to detect and identify potential catastrophic failures in flight and to reconfigure the aircraft system, allowing continuation of safe flight. The benefits of the concept were demonstrated using NASA's B-737 aircraft simulator. In simulation, the elevator of the aircraft was locked in a failure position, and the aircraft control system was restructured to accommodate this failure. The simulation showed that in the presence of this failure, as well as in wind shear, the B-737 could have continued safe flight and made a safe landing.

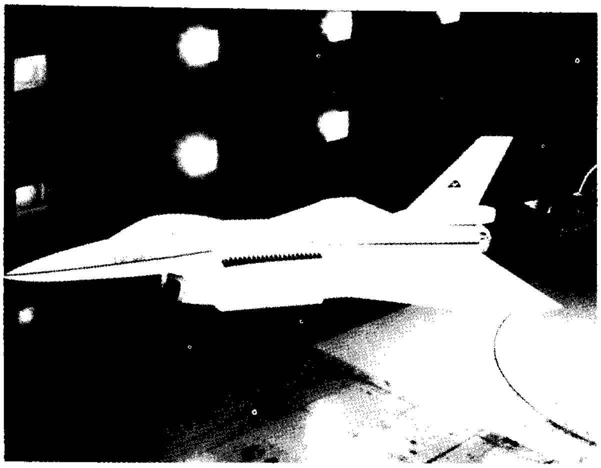
Human Factors. As automated features have been introduced into modern cockpits, the role of the pilot has changed from that of aircraft attitude controller to cockpit systems manager. The Man-Vehicle Systems Research Facility, a high fidelity simulator facility, has become fully operational and is used to study pilot supervisory control of aircraft automation, interactions between the crew and advanced computers, human-matched displays, and measures of cognitive workload. Last year, the simulator was used to evaluate side-arm controllers and wind shear simulation models.

As part of their flying tasks in highly automated aircraft, pilots must operate onboard computers which can be dangerously distracting. For this reason, computer scientists and cognitive psychologists conducted a study to improve the design of automation interfaces. The objectives were to reduce training time and to increase the speed and accuracy of accessing vital information. Results indicated that performance objectives could be achieved by matching the access paths in the computers to those preferred by pilots. The methodology developed for this study will be applied to cockpit-design complexities that have eluded quantitative analysis in the past.

Information Sciences. Scientific computers today are able to process complex algorithms, but setting up an algorithm is often cumbersome. The diverse hardware and software tools available for solving scientific problems are typically hard to use and poorly coordinated. To overcome this difficulty, the Research Institute for Advanced Computer Science at NASA's Ames Research Center has brought together computer scientists and disciplinary scientists to develop a unified, high-level interface for diverse and complex computing resources. This has resulted in a large collection of scientific processing power. Further applications of networking graphics and supercomputers will advance these efforts and raise the productivity of scientific computer users.

Systems Research

NASA's systems research and technology programs focus on the integration of various aeronautical disciplines. Results of disciplinary research provide an understanding of interactions among the components of aircraft systems. Work during 1985 was directed at powered lift, advanced turboprops, and rotorcraft technology.

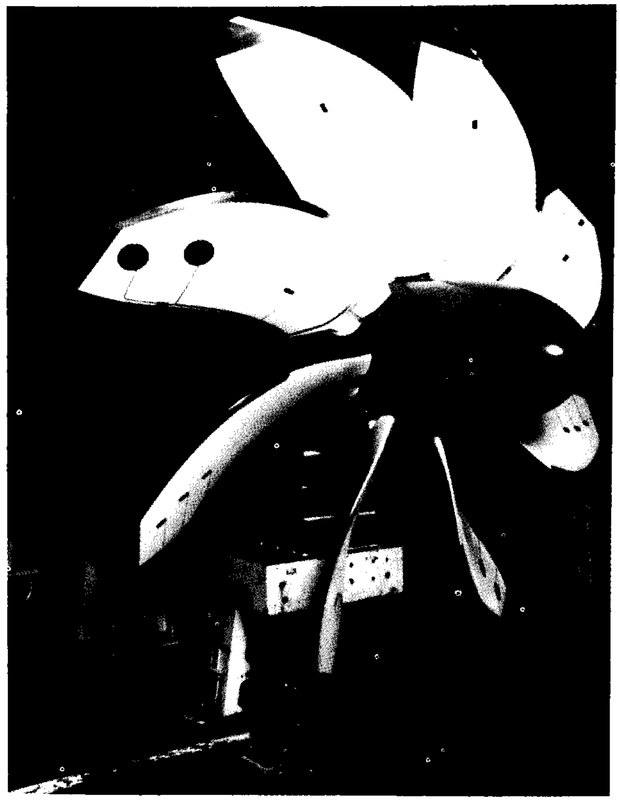


An ejector-lift Short Takeoff and Vertical Landing (STOVL) model in a wind tunnel.

Powered Lift. Research is under way to generate technology for advanced high-performance combat aircraft capable of short takeoff and vertical landing (STOVL). A joint NASA/Canada program has been initiated to test a large-scale STOVL flight model. The model uses ejector-lift and vectored thrust for STOVL operations in a transonic configuration. A planning activity with the United Kingdom has continued to make progress in defining a broad cooperative program directed at advanced STOVL technology. Four promising conceptual approaches have been identified for further investigation. To guide and govern the program, a draft Memorandum of Understanding has been approved by the Department of State for NASA and the Department of Defense to enter into with the Ministry of Defense of the United Kingdom.

Advanced Turboprop Program. Despite moderation of jet fuel prices in recent years, fuel costs remain a pressing problem for the airline industry and operators of business jets. Today, fuel accounts for more than 30 percent of total operating costs of airlines. There is much uncertainty as to whether there will be other price escalations, such as those experienced in the oil crises of the 1970's. Thus, the interest in increasing the advanced turbine/propeller engine, or turboprop program, which offers the potential for a 30-percent reduction in aircraft fuel consumption.

Through large-scale ground and flight testing, model scaling factors for critical technologies are being developed so research can be conducted using small-size models. A large-scale (9-foot diameter) single-rotation propeller has been ground tested. The aerodynamic results were close to prediction, thus satisfying ground testing requirements to permit flight evaluation of the structural and aerodynamic characteristics of the propeller in 1986.



A 9-foot diameter advanced turboprop.

Also successfully ground tested was the unducted fan concept, which offers the excellent fuel economy advantage of a turboprop but does not require a high-power gearbox. Results obtained show that the fuel consumption was slightly better than predicted.

Rotorcraft Technology. A principal objective of NASA's rotorcraft research is reduction of noise and vibration. In a series of tests, a helicopter with a liquid inertial vibration-absorption system demonstrated low vibration levels in flight. Also, a new analysis of coupled rotor/fuselage behavior has indicated significant potential for vibration reduction. These activities are being conducted in a special cooperative program involving NASA and U.S. helicopter manufacturers.

In another cooperative program with the rotorcraft industry, acoustic research shows promise of predicting accurately the high-speed impulsive noise and blade-vortex interaction noise of rotors. The research also indicates ways of alleviating or avoiding these predominant noise sources. U.S. industry has received the first release of a comprehensive noise prediction code.

Military Support

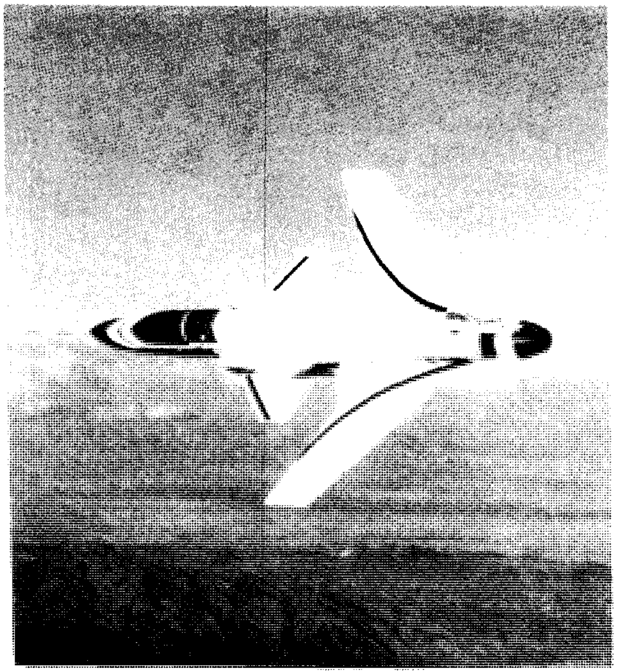
NASA conducts numerous joint programs with the Department of Defense to maintain the continued superiority of U.S. military aviation. These programs include both rotorcraft and high-performance aircraft.

Mission Adaptive Wing (MAW). The MAW program demonstrates use of variable smooth camber (fore to aft curvature) wing technology to provide dramatic improvements in aircraft payload, range, maneuverability, fuel efficiency, and handling qualities. The wing, covered by a flexible composite material, has a computerized system of sensors, controls, and internal hydraulic actuators that can change its contour. Flight testing began in 1985 on an F-111 aircraft. Tests to validate the performance benefits, including a potential range improvement of 25 percent, will be completed in 1986.

F-15 Highly Integrated Digital Engine Control (HiDEC). HiDEC is a joint NASA/Air Force/industry flight research experiment to develop technology for beneficial interaction of engine and flight controls. Flight research continued during 1985 on an F-15 aircraft modified for digital electronic flight and engine control, and is expected to be completed in 1987. The control technology involved allows the automatic adjustment of engine operating parameters, based on flight conditions. Compared to the performance of a standard F-15, the modified aircraft is expected to double the excess supersonic thrust.

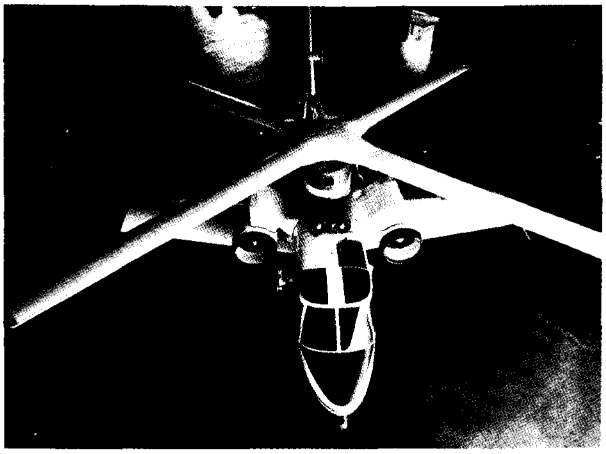
Oblique Wing Research Airplane. This joint NASA/Navy activity consists of the design, fabrication, and flight research testing of an oblique wing on an existing aircraft during transonic and supersonic flight conditions. The oblique wing, conceptualized over forty years ago by R. T. Jones of NASA, pivots in flight to form oblique angles with the airplane's fuselage. During takeoff and low-speed operation, such a wing would be at right angles to the fuselage or "straight." At higher speeds, it would swing around a pivot so that the leading edge on one side would be swept forward, and the other would be swept aft encountering less drag. This concept offers great aerodynamic efficiency at both high and low speeds. In 1985, a preliminary design contract was awarded to establish the basis for final design, fabrication, and installation of the oblique wing, and its associated systems, on the NASA F-8 Digital Fly-By-Wire aircraft. The flight research testing is planned for 1989.

X-29A Forward-Swept Wing Flight Demonstrator. In March, NASA began the flight research program of the highly advanced X-29 aircraft at Ames Research Center's Dryden Flight Facility. The X-29A features a unique forward-swept wing, made of composite materials, which offers weight reduction up to 20 percent compared to the weight of conventional aft-swept wings. In addition, the forward "canard" wings are computer adjusted 40 times a second to improve flight efficiency and aircraft agility. Flight test results have agreed with predictions. The X-29A aircraft and its various systems have demonstrated high reliability during the initial flight phase.



X-29A Forward-Swept Wing aircraft.

RSRA/X-Wing Rotor Flight Investigation. At the request of the Defense Advanced Research Projects Agency, NASA is managing and supporting a program to develop and flight test the X-wing rotor concept of the NASA/Army Rotor Systems Research Aircraft (RSRA). The X-wing rotor has four extremely stiff blades that can be transformed in flight into an X-shaped fixed wing. For takeoff and landing, hovering, and low speeds, the rotor operates in the spinning mode as a helicopter rotary wing. At a speed of about 200 miles per hour, the rotor is stopped and locked in place, providing fixed-wing lift for much higher speeds. In 1985, components of the X-wing rotor system were fabricated, tested, and assembled on a propulsion system test bed (PSTB) to evaluate system characteristics. The system has performed as designed in PSTB testing. A prototype digital fly-by-wire flight control computer has been built and is now being tested. Supporting research and technology conducted by NASA includes wind tunnel evaluations, piloted simulation, and technical guidance for the X-wing rotor. In 1986, RSRA/X-wing activities will focus on completion of the rotor system assembly, propulsion system tests, and preparation for flight testing.



The X-Wing Rotor Systems Research Aircraft (RSRA).

Convertible Engine. The convertible engine allows a gas turbine engine's output to be in the form of either shaft power or fan power. The transition from one to the other can be made in a continuous manner during engine operation. A test of the transient conversion requirement for an X-wing configuration vehicle has been completed. The results indicate that the propulsion technology for efficient conversion between shaft power and fan power in a military X-wing configuration has been established. Potential applications of this technology include the tilt fan and folded tilt rotor concepts.

Helicopter Air Combat Simulation. NASA's Vertical Motion Simulator (VMS) has been instrumental in helping the Army define handling qualities and flight characteristics of helicopters conducting low level air combat. The VMS allows a flexibility and safety factor that cannot be achieved in actual flight tests. The results will allow development of vehicle and system design specifications.

Safety in Air Transportation

NASA and the Federal Aviation Administration (FAA) closely coordinate research activities in order to meet the continuing challenge of providing a safer air transportation system for the Nation's growing number of air travelers.

Aircraft Icing. NASA is engaged in laboratory and flight investigations of icing on fixed-wing and rotary-wing aircraft. Icing can cause increased aircraft drag, reduced lift, stall, loss of engine power, and other hazards. The principal objective of icing research is to find solutions to aircraft icing problems. The research is focused on developing computer codes and methods for predicting ice accretion and its effect on unprotected surfaces; ice protection systems that minimize weight and power consumption; instrumentation for detecting and measuring ice accretion and icing cloud properties; and new instrumentation for detecting changes in aircraft performance due to icing and for assessing the icing threat in real time. In June 1985, NASA's Lewis Research Center conducted a symposium for industry on an Electro-Impulse Deicing System which holds promise as an effective, lightweight, low-power ice protection system for many aeronautical applications.

Wind Shear. The emphasis of research on wind shear, which is a sudden shift in wind velocity and direction often associated with severe storms, is on characterizing the condition and surviving it. The "microburst", the most violent form of wind shear, has been identified as the probable cause of many aircraft accidents. Also, in wind shear research, computational fluid dynamics codes are used to transform wind shear data into useful flight simulator models. The wind shear models have been incorporated into the Advanced Transport Operating System simulator. In addition, research has been conducted to evaluate an optimal automatic flight control system for penetrating regions of severe weather. Results indicate that use of the new control system design is much more effective in a severe wind shear and gust environment than use of the standard B-737 autoland system. The glideslope, altitude, and airspeed control is much tighter, and requires less elevator and throttle activity than does the conventional autoland system. Flight tests of this optimal control system, using NASA's B-737 aircraft, are planned for 1986.

Aviation Safety Reporting System. NASA continues to manage the Aviation Safety Reporting System (ASRS) for the FAA. Studies of the ASRS database in 1985 found significant increases in automation induced crew errors and runway transgressions. The studies also have shown that crews who have performed together for longer periods of time, even though they may be fatigued, are more productive and make fewer errors than crews who have just started working together.

Control Impact Demonstration. On December 1, 1984, NASA and the FAA jointly conducted a control impact demonstration with a B-720 aircraft. The purpose was to demonstrate and validate technology that would improve passenger survivability in crashes of transport aircraft. A fully instrumented, remotely piloted Boeing 720 aircraft was flown into the ground to obtain structural impact data and to assess the performance of an anti-misting fuel additive. High quality structural data obtained during the impact test are being used by the FAA in decisions for rulemaking and by NASA to validate structural impact prediction models.

Department of Defense

Space and space transportation systems have high priority in the Department of Defense (DOD), and continue to play a major role in the security of the United States and its allies. To complement the Space Shuttle, DOD is in the process of acquiring Complementary Expendable Launch Vehicles. In 1985, preparations continued for the first launch, scheduled for mid 1986, of the Space Shuttle from the West Coast Shuttle launch and landing facilities at Vandenberg Air Force Base, California.

In 1985, efforts continued to increase the survivability, autonomy, and reliability of satellite supporting systems crucial to the deterrence and containment of hostilities. The Global Positioning System expanded to seven satellites; and the precise geodetic positions provided to military and civilian users during tests of the System exceeded operational requirements.

The Air Force Space Command manages and operates the space assets of the Air Force. Since 1982, it has been the field agency responsible for day-to-day control of Air Force satellites, and for ensuring that they provide support to operational commanders. In addition, it functions as an interface between research and development activities and space system users; and it integrates long-range space planning, doctrine, and operational requirements.

In 1983 the Strategic Defense Initiative began. After completion in the 1990's of the necessary major research, a decision will be made on possible deployment of the resulting defensive systems.

In September 1985, the Secretary of Defense established the U.S. Space Command, located in Colorado Springs, Colorado. This unified command, composed of the Air Force and Naval Space Commands and an Army element, provides an organizational structure that will centralize responsibilities to make more effective use of space systems.

In December 1985, the Army Space Initiatives Study (ASIS) Group completed and delivered its report to the Army Space Council. The Group developed an operational concept for Army space activities and an Army Space Master Plan, including recommendations for space-related personnel management issues, an investment strategy, and a management plan with an organizational proposal. It recommended 53 individual initiatives consisting of various investment opportunities, and contains detailed recommendations regarding training and management of personnel involved in space activities. Finally, the Group recommended an organizational plan to ensure Army participation in the U.S. Space Command, and to provide a focus on space in Army staff activities, and within the Training and Doctrine and Army Materiel Commands. The Space Council referred the ASIS report to the Army Deputy Chief of Staff, Operations and Plans, for formal staffing.

Space Activities

Military Satellite Communications

MILSATCOM. Military Satellite Communications is a system that will provide communication linkages between decision makers and deployed forces worldwide. By coordinating the capabilities of specialized satellites and ground terminals, it can provide reliable and survivable communications to strategic and tactical forces over the full range of conflict and national emergencies. During 1985, military satellite communications continued to depend primarily on the Defense Satellite Communications System (DSCS), the Fleet Satellite Communications System (FLTSATCOM), and selected commercial Satellite Communications (SATCOM) circuits. The strategic and tactical nuclear-capable forces also were served by the Air Force Satellite Communications System (AFSATCOM), which uses transponder packages on FLTSATCOM, the Satellite Data Systems, and other host satellites. In the future, strategic and tactical satellite communications will depend on DSCS, Milstar, and ultra high frequency satellite systems.

Defense Satellite Communications Systems. The DSCS provides super high frequency satellite communications for secure voice and high data rate transmissions to support both defense and diplomatic users. Currently operating worldwide with three DSCS Phase II and one DSCS Phase III communications satellites in geostationary orbit, it supports forces for long-haul, moderate-to-high data rate communications.

The ground terminals of DSCS continue to be improved in capability and survivability. Added in 1985, were 20 medium-sized AN/GSC-39 terminals; 24 jam resistant, secure communications terminals; and 39 improved AN/GSC-52 terminals, which are more automated in their operation. Also, 4 gateway terminals, which permit communications between strategic and tactical users; and 2 Satellite Configuration Control Elements were added.

Between 1985 and 1986, selected DSCS control facilities will receive an operations support system that provides an automated means of allocating service to competing users. During 1985, four AN/MSQ-114 terminals approved for operational use with the DSCS III control subsystem were accepted and deployed for tactical use, and final acceptance testing was initiated on the AN/TSC-85A multi-channel and AN/TSC-93A single-channel tactical terminals.

Other procurements are planned to occur by 1987, predicated on the need for a more efficient semi-automated system control. Included are Frequency Division Multiple Access Control Subsystems, which monitor network terminal performance and relay information to major control terminals; Smart Multi-Circuit Terminals; and the Ground Mobile Forces Control Link. These components in the DSCS operations control system will provide an enhanced capability to monitor, control and reconfigure communications vital to national security.

Milstar. The Milstar communications satellite system will provide worldwide jam-resistant, survivable and enduring voice communications for the National Command Authorities. As a crucial part of the President's strategic modernization program, the system has been given high priority. In November 1985, preliminary design review of a spacecraft and satellite control segment was completed, along with payload and interface testing. The Air Force Space Command developed plans for deployment of the satellite control segment, which will allow spacecraft station keeping and maintenance operations during wartime. The Navy Joint Terminal Program office is responsible for overall management of the development of terminals to support the National Command Authorities, Joint Chiefs of Staff, and general terminal requirements of the service branches. The Air Force is responsible for airborne and some strategic ground terminals, and the Navy and Army for shipboard and ground terminals, respectively. In July 1985, the Navy demonstrated two competing prototype terminal designs using a Fleet Satellite extremely high frequency package. It plans full-scale development in 1986. Advanced development of the Army's Single Channel Objective Tactical Terminal (SCOTT) has been completed. SCOTT will operate in the extremely high frequency band and will provide survivable communications in wartime. In December 1985, an engineering development contract was awarded that will provide 15 terminals for testing in 1988; initial production is also expected in 1988.

Fleet Satellite Communications System. This system provides worldwide command and control for tactical and strategic forces of all U.S. military services. Ultra High Frequency (UHF) SATCOM, a segment of FLTSATCOM, is the backbone system for users communicating beyond line of sight, especially Navy users. It provides coverage worldwide from 70° north to 70° south, serving as a crisis and contingency system that will complement other satellite communications well into the 21st Century. It includes ground, ship, aircraft, and portable terminals; space segments; and control terminals. To date, four FLTSAT's and three Leased Satellites (LEASAT's) have been launched and are now operating in orbit. Another LEASAT and additional FLTSAT's will be launched between 1986 and 1988. When all LEASAT's become operational, the space segment will consist of four FLTSAT/LEASAT pairs. In 1991, a UHF satellite will replenish existing FLTSAT/LEASAT pairs in order to maintain vital command and control linkages to military forces.

Army Satellite Communications. The Army continues to develop and expand the worldwide Defense Satellite Communications System, FLTSAT/AFSAT, and Milstar satellite communications systems to satisfy strategic and tactical requirements. Specific responsibilities include development, procurement, and life cycle support of ground terminals and support systems.

Strategic Satellite Communications. In 1985, the Army spent considerable time and effort preparing the ground subsystem of the DSCS for increased capacity, reliability and survivability. Two new satellite configuration control elements were installed to support the operation of DSCS III satellites now being tested. Also, to enhance strategic terminal operations, a number of new digital communications subsystems were installed.

Tactical Satellite Communications. In 1985, use of satellite communications by ground mobile forces increased. Installation of the Multichannel Initial System's AN/TSC-85A and AN/TSC-93A terminals started in Korea. These terminals operate in the super high frequency band and use satellites from the DSCS; 200 terminals will be deployed worldwide within the next two years. In addition, production began on the Anti-Jam and Control Modem, which is a product improvement program to provide a jam resistant communications capability. The modifications provide more survivable communications, and more effective use of scarce satellite communications resources. Also, the AN/PSC-3 and AN/VSC-7 manpack and vehicular mounted UHF tactical satellite terminals were installed. These terminals provide a unique single-channel communications capability for Army Ranger and Special Forces.

Navigation and Geodesy

Global Positioning System (GPS). In October 1985, the last developmental GPS Satellite, Navstar II, was launched. Currently, seven GPS developmental satellites are performing excellently. Procurement of operational satellites was in its fourth year under a multi-year, 28 spacecraft, contract. The first operational launch is scheduled for 1987, with full operational capability planned for 1988.

Development of GPS receivers continued with selection of a contractor to produce user equipment. Test results obtained from host vehicles such as the F-16, B-52, UH-60, submarines, aircraft carriers and manpacks indicate that overall navigation performance meets or exceeds requirements. However, reliability and maintainability are lower than expected. The services will accept limited production, pending corrections for reliability and maintainability. In addition, the Defense Mapping Agency conducted acceptance tests of GPS geodetic receivers phased into operation in 1985, and will continue the tests in 1986. The ground control center currently located at Vandenberg Air Force Base, California, will be transferred in 1986 to the Consolidated Space Operations Center at Falcon Air Force Station, Colorado.

Geodetic and Geophysical Satellite. In March, the Navy's geodetic and geophysical satellite (GEOSAT) was launched. Its mission is to determine a global marine geoid by measuring small variations in the height of the ocean surface. With the completion of geoid measurements, the satellite will be repositioned into a repeat orbit to optimize oceanographic measurements of wave height and surface wind speed and to locate ocean fronts and eddies.

Meteorology and Oceanography

Defense Meteorological Satellite Program (DMSP). DMSP completed another year of providing critically important, secure, high-quality meteorological data to DOD strategic and tactical forces around the world. The multiyear procurement of four satellites initiated in 1983 continues on schedule, with a projected cost savings of $58.2 million.

Navy Remote Ocean Sensing System (N-Ross). The N-ROSS satellite is designed to measure ocean surface winds, sea surface temperatures, ocean fronts and eddies, polar ice conditions, atmospheric water vapor and significant wave heights. Its sensor derives its heritage from the SEASAT, NIMBUS, GEOSAT, and the National Oceanic Satellite System (NOSS) satellite projects. The scatterometer sensor, to study ocean surface winds, will be built under NASA's direction. The Air Force will manage launch, command and control functions; and the Navy will process N-ROSS data at the Fleet Numerical Oceanic Center, Monterey, California. The National Oceanic and Atmospheric Administration will distribute the data to federal agencies, private industry, and the academic community. Launch of the satellite is scheduled for September 1990.

Surveillance and Warning

Early warning satellites, complemented by ground-based radars and sensors, warn of potential ballistic missile attacks. Surveillance techniques that will allow detection of cruise missiles are under study. Included in the studies is the feasibility of detecting and tracking cruise missiles from space platforms. The Air Force has initiated technology assessments of cruise missile flights against low-contrast Earth backgrounds. Its Teal Ruby program will test infrared detection of air-breathing vehicles by an orbiting platform, and will provide data on the feasibility of various surveillance techniques. These data are vital for development of a space-based, wide-area surveillance system. In 1985, the Teal Ruby flight sensor completed radiometric and thermal vacuum testing, and was modified to allow retrieval by the Space Shuttle.

Antisatellite (ASAT) Program. The Space Defense program continued to develop a low-altitude, miniature-vehicle ASAT system. The primary purposes of an ASAT capability are to deter threats to space systems belonging to the U.S. and its allies, and to deny use by an adversary of space-based systems that provide support to hostile military forces. ASAT's will be launched from F-15 aircraft. In September 1985, the first intercept test against an object in space was conducted.

Strategic Defense Initiative. The Strategic Defense Initiative Organization is responsible for directing and coordinating programs of the Army, Navy, Air Force, Defense Nuclear Agency, and Defense Advanced Research Projects Agency that study defenses against attack by ballistic missiles.

The goal of the Organization is to assess the feasbility of key technologies so that a determination can be made in the 1990's on producing and deploying defense systems. Research is divided into five major elements:

- technologies for surveillance, acquisition, tracking, and kill assessment of ballistic missiles or their components during their boost, mid-course, and terminal trajectory phases
- consolidation of research on directed-energy weapons such as space and ground based lasers, X-ray lasers, and particle beams
- research on kinetic energy weapons to destroy, by direct impact, ballistic missiles or their components (In 1985, the Army demonstrated use of this technology using non-nuclear techniques.)
- systems analysis/battle management studies to determine effective structures for command and control elements of a defensive system
- research on survivability, lethality, and key technologies focusing on the survivability of defensive systems, the lethal capability against ballistic missiles, problems of electrical power in space, and launch vehicle requirements.

The results will permit future decision makers to make informed choices on whether to develop and deploy defenses against the ballistic missile threat to the United States and its allies.

U.S. Army Strategic Defense Command (USASDC). In July 1985, the Army Ballistic Missile Defense Organization was redesignated USASDC. It conducts a continuing research program involving the above five program elements of strategic missile defense. Its goal is to build a strong technological foundation from which a wide range of options for strategic defense can be developed.

The technology for terminal systems to defend strategic assets has been developed, and contracts have been awarded for the Terminal Imaging Radar and Airborne Optical Adjunct. In 1986, a contract will be awarded for the High Endoatmospheric Defense Interceptor. Technologies to support longer-range intercepts, while not as mature, are rapidly approaching the stage where new system concepts such as the Exoatmospheric Reentry Vehicle Interceptor System, Free Electron Laser, and Neutral Particle Beam may be demonstrated soon. Future efforts will focus on refining previous achievements, developing proof-of-principle technologies and conducting validation experiments.

Space Transportation

Future Space Transportation. DOD continues to participate in joint studies with NASA on next generation space transportation requirements, architecture and technology.

Expendable Launch Vehicles (ELV's). In 1985, DOD launched two Titan 34D and two Atlas E vehicles. In addition, two Scout vehicles were launched for DOD by NASA. In support of the President's national policy for assured access to space, DOD continued activities that will lead to the acquisition and launch of 10 Complementary ELV's (CELV's) between 1988 and 1992. They will be used as a complement to the Space Shuttle, and will be capable of boosting Shuttle-class, national security payloads into geosynchronous orbit.

In 1985, deactivation and storage of the 56 existing Titan II missiles continued, with 32 of them now in storage at Norton Air Force Base, California. Planning continued for converting Titan II's to ELV's; and a request for proposal, with a program start date in 1986, has been released.

Space Shuttle. The Department of Defense and NASA have worked together on the Nation's Space Transportation System. NASA has development and operational responsibilities for the Space Shuttle, including the East Coast Shuttle launch and landing facilities at Kennedy Space Center, Florida, and the Mission Control Center at Johnson Space Center, Texas. DOD's responsibilities for the Shuttle include development of the Inertial Upper Stage (IUS), one of the upper stages used to boost spacecraft into geosynchronous orbit, and operation of the West Coast Shuttle launch and landing facilities at Vandenberg Air Force Base, California. Modifications of NASA's facilities and equipment for classified operations at Johnson and Kennedy Space Centers and Marshall and Goddard Space Flight Centers are being funded by the Air Force. Construction of major facilities at Vandenberg is essentially complete, and installation of support equipment is well underway. Vandenberg will enable the Shuttle to launch satellites into polar orbit, a capability not achievable from Kennedy Space Center.

Upper Stage Programs. The Space Shuttle requires upper stages to boost payloads from low Earth orbit to geosynchronous orbit (GEO). They include the commercial Payload Assist Modules, PAM-D and PAM-A, which can carry 450 to 1,400 kilograms to GEO; the Air Force IUS, which can boost 2,300 kilograms to GEO; and the joint NASA-Air Force Centaur which will be able to transport 4,500 kilograms to GEO. The IUS made two successful flights in 1985.

Advanced Spacecraft Technology. In 1985, the Air Force continued work on its advanced spacecraft technology program. The program's primary objective is to increase satellite survivability, autonomy, performance reliability, and lifetime. The secondary objective is to use lighter, less complex, and more economical satellites than exist currently. The program focuses on computers, electronics, and power, and on technology planning. In 1985, the satellite autonomy project was completed, and a program to develop technology for space-qualified Very High Speed Integrated Circuits was started. Continued was development of microelectronics that are more capable and hardened. In addition, development was initiated of a high-efficiency solar panel and a high-density, space-qualified battery to support satellite operations.

Space Test Program. In 1985, the Space Test Program (STP) provided space flights for 17 experiments, including five reflights. In addition, six STP satellites remained in orbit where they are collecting data to use in the design of future DOD space systems. Fourteen of the 17 experiments were flight-deck quick response payloads for oceanographic, meteorological, and radiation measurements, as well as laser tracking and biotechnology. The remaining three were flown in NASA Get-Away Special canisters in the Shuttle's payload bay. They included space ultraviolet measurements and deployment of the Global Low Orbiting Relay Satellite.

Aeronautical Activities

Fixed-Wing Programs

Bomber Development (B-1B). In June 1985, the first operational B-1B aircraft were delivered to the Strategic Air Command. The B-1B's operational capabilities were tested at Dyess Air Force Base, near Abilene, Texas, and at Edwards Air Force Base, California.

Advanced Tactical Fighter (ATF). The ATF program is developing the next-generation Air Force fighter to counter the Soviet threat in the late 1990's and beyond. Improving on the design of the F-15, the ATF will perform counterair operations in enemy airspace with an effective "first-look, first-kill" capability. It will incorporate both superior performance and survivability features, as well as improved reliability and maintainability. Its improved capabilities will be made possible by significant technological advances in the areas of signature reduction, aerodynamic design, flight controls, materials, propulsion, sensors, signal and information processors, and integrated avionics. It will reach an initial operational capability in 1995.

In August 1985, the ATF program completed an Air Force Systems Acquisition Review Council milestone. A request for proposal was released in October for the Demonstration/Validation phase. Contractor proposals were requested by February 1986, with a source selection scheduled for mid-1986. The Demonstration/Validation phase is intended to reduce technical risks for full-scale development in 1989, and to develop preliminary designs and tradeoffs to meet affordable goals. Other accomplishments in 1985 included development and demonstration of avionics processors and computers, and component testing on the Joint Advanced Fighter Engine, the technology demonstrator leading to the ATF engine.

C-5. In 1985, wing modifications were completed on 50 C-5A aircraft. Modification of the entire fleet of 77 aircraft is expected to be completed by July 1987. It will allow the C-5A to attain full mission capability and will extend aircraft service life by 30,000 flight hours. The production program for 50 C-5B's will use a wing of the same basic design. The program is on schedule, with the first aircraft delivered in December 1985. Both the C-5A and C-5B are expected to operate well into the next century.

C-17. The C-17 transport aircraft will provide the minimum intertheater airlift requirements specified in a study mandated by Congress. The aircraft will replace the capability lost from retiring C-130's and some C-141's. Full-scale development efforts will continue through 1986, leading to production in 1988, and an initial operational capability in 1992.

T-45TS. The Secretary of Defense authorized development of a fully integrated naval aviator training system which includes aircraft, simulator, and related equipment. The T-45TS replaces the T-2C, intermediate, and TA-4J, advanced, jet training aircraft. It is a carrier-capable derivative of the British Aerospace Hawk aircraft. First flight of the aircraft is scheduled for 1987; initial operational capability is planned for 1990; and production of 300 aircraft, 32 simulators, and associated training equipment will continue through 1995.

Cruise Missile Programs

Air Launched Cruise Missile (ALCM). The ALCM is a long-range, subsonic missile designed for deployment from the B-52G and H. An inertial navigation system guides the missile to the target. The system is updated after launch by terrain correlation matching. A total of 1,715 missiles will be delivered to the Strategic Air Command by October 1986. A B-52G carries 12 ALCM's on two external pylons, and retains the capability of carrying short range attack missiles and gravity weapons internally. Future plans include loading cruise missiles externally and internally on B-52H's, for a total of 20 missiles per aircraft. The B-1B will also be capable of carrying cruise missiles. ALCM missiles are deployed at five B-52 bases, with deployment underway at two additional bases.

Ground Launched Cruise Missile (GLCM). Air Force deployment and testing of GLCM's continue on schedule. Initial operational capabilities were established at Greenham Common, United Kingdom in December 1983; Comiso, Italy in March 1984; and Florennes, Belgium in March 1985. In June 1984, Follow-on Operational Test and Evaluation (FOT&E) Phase I was completed, demonstrating that the GLCM weapons system can perform its mission effectively. In July 1984, FOT&E Phase II was initiated and will continue to gather data from ground, communication and flight testing through June 1986.

Helicopter Programs

AH-64 Apache Advanced Attack Helicopter. In December 1985, the 59th AH-64 Apache helicopter was delivered to the Army, marking completion of the second production contract. The Army procured a total of 309 aircraft out of the 675 programmed, and deployment to all Training and Doctrine stations is nearly complete. In April 1986, the first unit will begin training at Ford Hood, Texas.

CH-47 Modernization. The modernized medium-lift helicopter, the CH-47D, provides responsive movement of ammunition, repair parts, troops and vehicles. The CH-47's outdated technology and age dictated modernization in order to maintain Army medium-lift capability. The CH-47D provides substantial improvements in reliability, maintainability, flight safety and survivability. In April 1985, the Army awarded a multiyear contract to modernize 240 CH-47A, B, and C aircraft to the D configuration. A proposed second multiyear contract from 1990 to 1993 would complete a program total of 468 CH-47D's.

UH-60A Black Hawk. The Black Hawk is the helicopter the Army needs to implement the airmobility doctrine of land forces in the 1980's and 1990's. This aircraft provides the combat support and combat service required to sustain ground forces engaged in land warfare. By November 1985, the Army had accepted 700 Black Hawk helicopters for high priority units in the United States, Europe, Panama, and Korea. In 1986, deliveries will continue to active units in the United States, Europe, and Japan, and to the National Guard and Army Reserve. The Black Hawk provides improved capability to carry a combat-equipped squad of 11 men, or comparable cargo, in adverse weather, day or night.

HH-60A Night Hawk. The Air Force completed HH-60A airframe flight tests, and modified test aircraft with avionics required to perform combat search and rescue missions. In July 1985, integration of avionics was completed for low-level navigation at night and under the weather, and a one-year flight test program began. Although modernization of combat rescue capabilities is badly needed, the HH-60A program was canceled due to budget constraints. Reinstatement must be evaluated against overall Air Force priorities.

V/STOL Programs

V-22 Osprey (Formerly JVX). The Osprey is designed to provide the Marine Corps, Navy, Air Force and Army with a multi-mission Vertical/Short Takeoff and Landing (V/STOL) capability for the 1990's and beyond. It will satisfy operational requirements such as Marine Corps assault vertical lift, Navy combat search and rescue, Air Force special operations, and Army medium cargo assault lift. In April 1983, the Preliminary Design Phase began; in 1986, a decision leading to full-scale development is expected. Powered model, aeroelasticity, and large-scale rotor performance tests were completed. Results of these tests will lead to detail design of the Ground Test Vehicle, which is critical to a first flight, expected in 1988.

Aeronautical Research and Development

X-29 Advanced Technology Demonstrator. The X-29, the first X-series aircraft in over a decade, has completed its first year of flight testing. This innovative program demonstrates advanced high-risk, high-payoff technologies for future consideration. Exploitation of these technologies will improve future fighter aircraft performance, and will reduce the time, risk, and cost of future development. It is a joint DARPA/NASA/Air Force program that expands significantly the existing data bases for advanced composite research, aerodynamic and structural analytical design methods, design techniques of digital flight control systems, systems integration, and test and evaluation capabilities. The flight testing is being conducted by a joint government/industry team at NASA's Dryden Flight Research Facility at Edwards Air Force Base, California. By November 1985, 21 flights had been flown and test results met or exceeded predictions in all technical areas. The first X-29 produced will continue to gather research data, and strong emphasis will be placed both on the rapid transfer of test results to corporate and government users through the DARPA X-29 Future Applications Committee, and to validation of advanced aeronautical concepts. A second aircraft has been built, and the Air Force intends to use it to conduct a high angle-of-attack testing program, in cooperation with DARPA and NASA.

Advanced Fighter Technology Integration (AFTI). In 1985, an infrared sensing and tracking system was installed in the AFTI test aircraft at Edwards Air Force Base. The fully integrated system provides highly accurate, maneuvering attack against ground targets from very low altitudes, and improved air-to-air effectiveness. Technologies in the AFTI program will be used to improve the performance of future aircraft such as the Advanced Tactical Fighter.

Hypersonic Cruise/Transatmospheric Vehicle. DARPA, and the Air Force, Navy, Strategic Defense Initiative Organization, and NASA are investigating technology for a liquid-hydrogen fueled, airbreathing ramjet/scramjet and/or rocket-propelled vehicle capable of operating at hypersonic speeds. This technology would allow a horizontal takeoff aircraft to cruise at Mach 6 to 12 above 100,000 feet in the atmosphere or into space as a single-stage-to-orbit vehicle.

The goal of this research is "proof-of-concept" tests of a hypersonic propulsion system capable of operating efficiently at speeds from take-off to orbit. Technologies, such as those for advanced materials, actively cooled structures, lightweight tank and engine/airframe integration concepts, needed to usher in a new generation of airbreathing, hypersonic, transatmospheric vehicles, also will be pursued.

X-Wing. The X-wing combines the vertical lift efficiency of a helicopter with the speed, range, and altitude performance of a transonic, fixed-wing aircraft. For lift and control, it operates as a rigid rotor helicopter that uses circulation control instead of blade pitching. When in forward flight aloft, the X-wing converts to a fixed-wing configuration. When the rotor is stopped and the fixed blades are swept both forward and aft, the aircraft is capable of transonic speeds. At its Critical Design Review in 1985, the Joint DARPA/NASA X-wing program passed a major milestone. The major X-wing components approved were the 56-foot-diameter rotor and bearingless hub, the pneumatic valving system for blade cyclic lift-control, a high-torque clutch and brake, and a highly advanced digital fly-by-wire control system, that provides active rotor stabilization and high-harmonic vibration suppression. Also in 1985, the full-scale rotor system, with all drive components, was fabricated; and initial subsystem testing was initiated. The flight-control computer began initial check-out in a full-vehicle simulation laboratory, which included all flight hardware. In 1986, all the full-scale components will be integrated into a Propulsion System Test-Bed which will allow dynamic validation of the components and the flight-control system.

Rotorcraft System Integration Simulator (RSIS). RSIS is a joint Army/NASA demonstration and validation program that will provide vital information for helicopter development through simulation of rotorcraft flight dynamics, as well as solutions to many of the problems associated with developing new or improving old aircraft. The problems include systems integration, the effectiveness of weapons systems on rotorcraft and flying qualities. As part of the RSIS program, which will end in 1986, the Army will develop software for potential use in all flight training simulators.

Light Helicopter Family (LHX). The Advanced Rotorcraft Technology Integration program supports full-scale development of a family of Light Helicopters, with deployment expected in late 1986. The goal of the program is to develop both the system specifications for an Advanced Integrated/Automated Cockpit and the associated electronic architecture for LHX development. The practicality of a single crew member concept will also be considered in this program. Previous research efforts have shown that an integrated and automated cockpit, and associated electronic architecture, could provide the LHX and existing helicopters with improved characteristics. Some of them are improved communications and weapon system management, more accurate navigation, better target acquisition, and reduced pilot workload.

Microwave Landing System (MLS). In 1985, the Air Force prepared a request for proposal to acquire mobile MLS equipment and commercial MLS avionics. In addition, DOD continued to work closely with the FAA on fixed base MLS acquisitions which are planned for 1987. A second FAA competitive multiyear contract will be awarded in September 1987 for 700 systems, approximately 200 of which will be for DOD. Participation continued in the National MLS and the Tri-Service Tactical MLS. In 1985, under an FAA contract for the aviation training center at Ft. Rucker, Alabama, the Army procured two National MLS systems for delivery in 1988. The system will allow the Army to continue operating in the civilian and NATO aeronautical structures.

Avionics. Tri-service efforts continued with the Digital Audio Distribution System which uses state-of-the-art voice-digitization and noise-reduction techniques to distribute audio and data signals throughout aircraft. Also, the Navy joined the Air Force/Army Integrated Communications, Navigation, Identification Avionics program. This program will consolidate aircraft radio signals into an integrated unit through the use of digital avionics that are resistant to jamming and interception. In 1985, efforts continued on programs to improve electronics that reduce pilot workloads and enhance combat effectiveness. The new technologies used will result in significant space and weight savings.

Army Aeronautical Technology Research. The purpose of this program is to increase operational effectiveness of helicopters, reduce life cycle costs, and improve systems integration analysis, and flight simulation capabilities. The program includes research in the areas of aerodynamics, structures, propulsion, reliability, maintainability; safety and survivability, subsystems, mission support, flight simulation, and man-machine integration. In 1985, research projects undertaken were:

- evaluation of concepts for protecting helicopters against nuclear, biological and chemical agents
- flight testing of the icing severity-level indicator system
- development of analytical and testing techniques to determine crack growth in composites damaged in combat, through maintenance or accidents, or during manufacture
- assessment of aircraft subsystems to determine which potentially could be used in advanced optical concepts for flight control systems
- development of computer voice recognition and generation for new radar warning receivers
- development of preliminary test plans, and construction of an advanced main rotor for testing in a Dutch wind tunnel, unique in its capabilities for fidelity measurements.

Advanced Composite Airframe Program (ACAP). ACAP is a demonstration program involving design, fabrication, and testing of advanced composite materials for rotorcraft and secondary airframe structures. The program developed a Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) capability that significantly reduces the time for design and analysis. ACAP designs fulfill the most complete military requirements ever attempted for rotorcraft airframes, including requirements for crashworthiness, ballistic tolerance, and radar cross section reduction. Application of composite materials to rotorcraft structures will reduce airframe acquisition costs by 17 percent and weight by 22 percent. In addition, composite materials will reduce the need for repair and maintenance. In 1986, analysis of all laboratory and flight test data will be completed. The results will enhance the composite technology data base and its application to future rotorcraft systems.

Advanced Digital-Optical Control System and Flight Demonstrator Program. The program goal is to provide technology for engineering development of a battlefield-compatible flight-control system. By improving the ability to handle aircraft and decreasing pilot workload, this system will enhance the mission capabilities of aircraft. Specific objectives of the program are to:

- demonstrate the feasibility of providing digital-optical controls for helicopters with performance equal to that of mechanical flight control systems
- provide supporting data for future production of digital-optical flight control systems
- provide guidelines for handling qualities and control characteristics for digital-optical flight-control systems. Application of this technology will provide such benefits to next-generation Army aircraft as improved handling and flight safety, and reduced maintenance requirements, weight, cost and vulnerability to lightning, electromagnetic energy and nuclear radiation. In November 1985, flight testing began.

Remotely Piloted Vehicle (RPV). The Army is developing RPV's which, among other things, will satisfy needs for reconnaissance, target acquisition and electronic warfare. The Aquila Target Acquisition/Designation and Aerial Reconnaissance System is under development, with Operational Test II scheduled for September 1986. In accordance with a Congressional directive, and with guidance provided by the Joint Chiefs of Staff and the RPV Joint Requirements Management Board, a joint program will be established by the Army and Navy to evaluate off-the-shelf air vehicles and payloads.

Space and Aeronautics Support

Consolidated Space Operations Center (CSOC). CSOC consists of a Satellite Operations Complex (SOC) and a Shuttle Operations and Planning Complex (SOPC). The SOC will share the satellite control workload with the Satellite Test Center (STC), while the SOPC will provide facilities for secure flight planning and flight operations for military Space Shuttle missions. Besides augmenting present control capabilities, CSOC will strengthen U.S. space posture by eliminating vulnerabilities in satellite control at the STC and the Johnson Space Center during Space Shuttle missions.

CSOC will be activated on a schedule consistent with the need for facilities and communications for the Global Positioning System Master Control Station. In 1985, construction of CSOC's buildings at Colorado Springs, Colorado, was nearing completion, and a physical security systems contract was awarded. A Satellite Mission Control Center will be activated in 1987, followed by a second Center in 1988. In 1989, SOPC will provide limited Shuttle flight planning; and in 1992, limited Shuttle flight control will begin.

Air Force Satellite Control Facility. In 1985, the Air Force Test Center at Sunnyvale, California, supported 55 DOD and NATO satellites in orbit.

Eastern Space and Missile Center (ESMC). ESMC, at Patrick Air Force Base, Florida, provides developmental and operational launch services for the Army's Pershing I and II missiles, the Navy's Poseidon and Trident missiles, and the Air Force's short-range attack missiles. It also supplies launch and support services for NASA and DOD satellites, and continuous tracking of space objects. In 1985, ESMC supported 27 ballistic missile tests, 17 major space test operations, and 9 Space Shuttle launches.

Western Space and Missile Center (WSMC). WSMC, at Vandenberg Air Force Base, California, provides developmental and operational launch services for the Air Force's Minuteman and Peacekeeper missiles, space vehicles of NASA and DOD requiring polar orbits, and tracking and data acquisition support for aeronautical tests of the B-1B and cruise missiles. In 1985, WSMC supported 8 major space tests, 18 ballistic missile launches, including 4 launches of Peacekeeper.

White Sands Missile Range (WSMR). In 1985, support of aeronautics and space programs of DOD and NASA continued at WSMR, New Mexico. Launch, flight, and recovery services included ground and flight safety, range surveillance, command and control activities, and associated data acquisition and analysis. Space Shuttle activities were post-qualification tests on the orbital maneuvering system and the forward and aft reaction control systems, operation of the ground terminal of the Tracking and Data Relay Satellite system, and Shuttle flight and landing support. Other activities included upper atmospheric soundings using rockets and balloons, and a variety of astronomical test programs.

Kwajalein Missile Range (KMR). Located in the Republic of the Marshall Islands, KMR is the major range for testing defensive and strategic offensive missiles. In 1985, operational tests were conducted on Minuteman missiles and developmental tests were conducted on Peacekeeper missiles.

RAND/Arroyo Center. The RAND/Arroyo Center surveys space technologies to fulfill needs of the Army, and supports the Army Space Initiative Study. It provided an independent assessment of the Army's role in space through its report entitled "Army Exploitation of Space."

Armament Division (AD). The AD, at Eglin Air Force Base, Florida, conducts research, engineering development, test evaluation and initial acquisition of Air Force non-nuclear munitions. It operates 43 aircraft, and uses 50 instrumented test ranges covering 724 square miles of land, and 86,500 square miles of water, extending nearly 240 miles south into the Gulf of Mexico. AD has tested the Advanced Medium Range Air-to-Air Missile, the Airborne Self Protection Jammer, and the French Durandal runway cratering munition.

Arnold Engineering Development Center (AEDC). The AEDC, located at Tullahoma, Tennessee, conducts engineering development tests for both government and commercial users. In 1985, it supported projects and programs such as Peacekeeper, Space Shuttle, Small Intercontinental Ballistic Missile, Trident II, Strategic Defense Initiative, and Short Takeoff and Landing fighter technology.

Air Force Flight Test Center (AFFTC). AFFTC, at Edwards Air Force Base, California, is an ideal test area with a large air space, dry lake beds, isolation, and highly instrumented ranges. This unique facility provides support for many users, including NASA's Dryden Flight Research Facility, the Army Aviation Engineering Flight Activity, and the Air Force Rocket Propulsion Laboratory. In 1985, the Center supported space, tactical, and strategic systems and activities such as the Space Shuttle, B-1B, F-15, F-16, F-16XL, F-20, X-29, B-52 avionics modifications, antisatellite weapons, Advanced Fighter Technology Integration, and air and ground-launched cruise missiles.

4950th Test Wing. The 4950th Test Wing, based at Wright-Patterson Air Force Base, Ohio, tests military systems, subsystems, and components for the Air Force Systems Command (AFSC). In 1985, the 4950th Test Wing continued support of AFSC test and modification programs, and of the Advanced Range-Instrumentation Aircraft, which serves key telemetry, data processing, and command and control functions during aeronautical flight testing and space missions.

6585th Test Group. The 6585th Test Group is located at Holloman Air Force Base, New Mexico, and is responsible for operation of the Central Inertial Guidance Test Facility, the Radar Target Scatter Facility, and the High Speed Test Track. These facilities support inertial navigation system testing, high-speed, high-acceleration sled track simulations, and antenna and radar cross-section measurements. In 1985, programs supported were the B-1B, Trident, Advanced Medium Range Air-

169-254 0 - 86 - 3

to-Air Missiles, and Crew Escape Systems Technology. The Test Group is also the airspace manager for the White Sands Missile Range.

Relations with NASA

Aeronautics and Astronautics Coordinating Board

The Aeronautics and Astronautics Coordinating Board (AACB) is the major forum for reviewing, discussing and coordinating policies and programs of mutual interest to DOD and NASA. It is cochaired by the Under Secretary of Defense for Research and Engineering and the Deputy Administrator of NASA. Interagency coordination takes place through AACB panels on Aeronautics, Manned Space Flight and Launch Vehicles, Space Flight Ground Environment, Space Research and Technology, and Unmanned Spacecraft. Under direction of the AACB, a NASA/DOD Space Transportation System Master Plan was developed. Published in March 1985, it defines the base-line Space Transportation System (STS), and its present, planned, and projected operational capabilities; defines STS operating structure for NASA and DOD; assesses programs, and capabilities; and identifies system shortfalls.

Department of Commerce

Department of Commerce agencies participating in the Nation's aeronautics and space program during 1985 were the National Oceanic and Atmospheric Administration, National Bureau of Standards, and National Telecommunications and Information Administration.

The National Oceanic and Atmospheric Administration conducts research and gathers data about the oceans, atmosphere, space, and Sun, and applies this knowledge to products and services that benefit all Americans. It operates the Nation's civil environmental satellite systems, using their data to assess the effect of natural factors and human activities on global food and fuel supplies and on environmental quality. It observes and forecasts weather conditions, provides warnings of severe weather, and assists community-preparedness programs for weather-related disasters; prepares charts and coastal maps for geodetic research; and improves utilization and conservation of marine life.

The National Bureau of Standards maintains and develops national standards of measurement and provides government, industry, and academia with the measurement services and fundamental physical, chemical, and engineering data to achieve national goals. It supports space systems, atmospheric and space research, and aeronautical programs.

The National Telecommunications and Information Administration is the principal telecommunications policy advisor to the President. It develops and coordinates Executive branch policy in telecommunications and information, manages the radio spectrum assigned for federal use, provides technical support to international telecommunications conference activities, and provides technical assistance in telecommunications matters to other federal agencies.

Space Systems

Satellite Operations

Polar-Orbiting Satellites. During 1985, the Nation's primary operational polar weather satellites were NOAA 8 and 9, orbiting the Earth about the poles in Sunsynchronous orbits and providing environmental observations of the entire Earth four times each day. NOAA 8 crosses the equator southward at 7:30 a.m. local time, and NOAA 9 Northward at 2:00 p.m. These satellites carry four primary instruments: Advanced Very High Resolution Radiometer, the TIROS Operational Vertical Sounder, the Argos Data-Collection and Platform-Location System, and the Space Environment Monitor.

NOAA 8 and NOAA 9 are the first and second in a series of new Advanced TIROS-N spacecraft and carry additional instruments for Search and Rescue. NOAA-8 failed on June 12, 1984, and was reactivated on May 10, 1985. NOAA 6 filled in for NOAA 8 and was able to support most of the primary mission requirements. NOAA 8 tumbled again on October 30, 1985, and was recovered and reactivated on December 5, 1985. It will be replaced after the launch of NOAA G in June 1986.

NOAA 9. This satellite, NOAA F before its launch on December 12, 1984, fulfills the primary National Weather Service requirement for data to support the limited fine-mesh model used to predict weather for the continental United States. It carries a 3-instrument array of sensors furnished by NASA for measurement of Earth radiation budget factors, including backscatter to space of solar ultraviolet light and Earth-radiated thermal (infrared) radiation. These instruments on the NOAA F spacecraft work in concert with instruments on NASA's Earth Radiation Budget Satellite.

Geostationary Satellites. The GOES 6 satellite of NOAA's Geostationary Operational Environmental Satellite (GOES) system provided imaging and sounding data during 1985. It was placed at 98° west for the summer/fall hurricane season and then at 108° west for maximum coverage of winter weather coming off the Pacific Ocean and Gulf of Alaska. The next launches of GOES spacecraft are scheduled for 1986.

NASA, acting for NOAA, has contracted for satellites of the "GOES-Next" series (GOES I-M) planned for flight during the 1990's. The request for proposal was released June 29, 1984 and Ford Aerospace and Communications Corporation was selected to build the satellites of this series. The contract was awarded in October 1985. Sounder and imager instruments will be built by ITT.

Commercialization of Land Satellites (Landsats). In accordance with P.L. 98-365, a Landsat commercialization contract was negotiated with the successful bidder, the Earth Observation Satellite Company (EOSAT). The contract between the United States and EOSAT was signed on September 27, 1985. EOSAT has assumed day-to-day management and operational responsibility for Landsat 4 and Landsat 5 spacecraft through February 1987, and for the design, acquisition, launch, and operation of the follow-on Landsat 6 and Landsat 7 spacecraft and ground systems through 1994. The Landsat system currently consists of two Earth-orbiting satellites (Landsats 4 and 5) and a command, control, and data processing facility located at the Goddard Space Flight Center in Greenbelt, Maryland. Data distribution, archiving, and additional processing facilities are provided by the Depatment of Interior's Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota.

Landsats 4 and 5 carry identical Earth-observing sensors. The Multispectral Scanner (MSS) measures reflected or emitted energy in four visible and near-infrared spectral bands and provides 80-meter spatial resolution. The Thematic Mapper (TM) operates in seven spectral bands with 30-meter spatial resolution in six bands and 120-meter resolution in a thermal band. While Landsat 4 is capable of supporting only the MSS portion of its mission, Landsat 5 is supporting full mission requirements for both MSS and TM.

Satellite Data Services

The GOES Data Collection System (DCS) relays environmental data in realtime from remotely located Data Collection Platforms (DCP's). The DCS ground system is physically limited to 5,000 Platform Data Files (PDF's) in its data base. To expand the capability of the system, an off-line data base was created which contains all PDF's assigned to the DCS. Periodically, inactive PDF's are removed from the on-line system to prevent reaching the saturation number of 5,000. There are 6,223 DCP's assigned to the GOES DCS, of which 4,990 are contained in the on-line system and 3,400 are active. The DCS had an increase of 1,256 DCP assignments during 1985. Data are distributed to 68 national and 28 international users, and there are 29 passive, direct-readout stations (42 U.S. and 5 non-U.S.). The GOES DCS reliability was 99 percent for the year.

A GOES DCS Users Catalog was completed and disseminated in 1985. It contains DCP location, data collected, user identification, and address of all DCP's operating in the system.

WEFAX. The Weather Facsimile service continues to use three GOES spacecraft to broadcast satellite imagery, meteorological analyses and prognoses, operational messages, and ephemeris bulletins. The number of known users totals 205 (100 U.S. and 105 non-U.S.). In 1985, broadcast schedules were changed so that 560 products are broadcast each day.

GOES VISSR Atmospheric Sounder (VAS) Assessment. During the spring of 1985, GOES VAS data covering the central United States were used by the National Severe Storms Forecast Center to improve techniques for forecasting severe weather. The VAS data products evaluated for the Center included temperature and moisture profiles, stability indices, and several image products. Data were made available four times a day from March through October. In June 1985, coverage by VAS was modified to support operations at the National Hurricane Center. Throughout the hurricane season, VAS data were used to monitor the development, strength, and movement of tropical storms in the Gulf of Mexico, the Atlantic Ocean, and the Caribbean Sea.

Geophysical Data Bases. The National Geophysical Data Center archives, publishes, and analyzes various geophysical data bases that include space environment and cryospheric data recorded by NOAA satellites and some NASA and DOD satellites. Satellite data archives that expanded during 1985 include those from the GOES Space Environment Monitor, the Defense Meteorological Satellite Program (DMSP) electron and ion detector, the DMSP nighttime auroral imager, and DMSP visual and infrared images of clouds, snow, and ice illuminated by sunlight or moonlight. To support NASA's International Sun-Earth Explorer-3 and Dynamics Explorer programs, analysis was undertaken of ground-based records of magnetic variations.

Cryospheric Data Management System. The National Snow and Ice Data Center started a Cryospheric Data Management System to process, archive, and distribute passive microwave data recorded by DMSP satellites. Satellite launch is expected in mid 1986.

Satellite Anomaly Data Base. The Solar-Terrestrial Physics Division of NOAA constructed a data base to document the relationship between solar activity, space environment changes, and consequent problems with operation of geostationary and polar orbiting satellites. The current data base contains dates, times, and anomaly information from geostationary satellites operated by

U.S. industry, NOAA, NASA, Japan, India, and the European Space Agency, with contributions anticipated from Canada, Australia, and the Department of Defense. This data base will be merged with space environment data and will be expanded to include data on polar-orbiting satellite anomalies. A highly successful workshop was convened in Boulder, Colorado, in October 1985 to discuss the engineering and scientific aspects of these problems.

Program for Regional Observing and Forecasting Services. In cooperation with the National Center for Atmospheric Research, this NOAA program established a GOES direct-readout ground station in Boulder, Colorado, in 1981. The program developed and tested various techniques to combine satellite, radar, surface meteorological network, and ground-based sounding data to produce improved short-term (0 to 12 hours) and real-time, local-scale forecasts for severe storms and flash floods. During the summer of 1985, it ingested, processed, and displayed real-time, rapid-scan VISSR data, VAS data products, and VAS processed soundings on a work station that also displayed real-time Doppler radar imagery. Forecasts prepared from combined data sets will lead to exciting future applications of these advanced sensors in mesoscale diagnosis and forecasting. This program is now developing more quantitative VAS products to be used in future testing and operations. A major modification of the satellite ground station will occur in 1986, when digital satellite data will be distributed in a new data format. Currently, the program is adapting the satellite ingest and product generation tasks for integration into the Operational Weather Education and Research (POWER) environment. This will provide users of the POWER system direct access to real-time geostationary meteorological satellite data.

Domestic Training. NOAA is committed to providing training on applications of satellite sensing. In coordination with the National Weather Service, the Department of Defense, and other satellite data users, NOAA provided training to more than 700 scientists and weather forecasters, and briefed almost 350 others, during 1985. Topics covered included basic and advanced imagery interpretation (still photo and imagery in motion), heavy rainfall estimation, tropical cyclone analysis, and severe storm, aviation, oceanic, and moisture-channel applications.

Satellite Data Uses

Space Shuttle Support. Imagery and digital data from NOAA polar satellites continue to be used by the Space Shuttle Earth Observations Project at NASA's Johnson Space Center, Houston, Texas. High-resolution satellite imagery is used in preflight briefings for Shuttle crews and during the missions to plan orbit-by-orbit Earth observation activity. For example, agricultural fires in Brazil, a volcanic eruption in the Marianas Islands, and upwelling off the coast of northwestern Australia were detected by Advanced Very High Resolution Radiometer (AVHRR) imagery and reported to the crew, who subsequently documented the events with photographs. Polar satellite data and shuttle photography are used to assess environmental trends and phenomena such as changes in coastlines, drought-stricken areas, and locations of ocean currents.

Color-Coded Global Vegetation Index Product. The NOAA global vegetation index product can now be produced in a color-coded format. The product has the following interactively derived features: five shades of green for vegetation, one shade of blue for water, and one shade of brown for nonvegetated areas; geopolitical boundaries; mask for water areas; vegetation-index color bar and values; and descriptive annotation. This new product is derived from data collected by NOAA polar-orbiting satellites and gives a more "natural" presentation of the global vegetation state.

Global Fire Product. An experimental product has been created that shows global fire activity. The product is based on data from the AVHRR 3.8-micrometer channel aboard the NOAA polar-orbiting satellites. This channel is sensitive to high-temperature targets such as fires. The experimental global fire product depicts the fire activity as white "hot" spots displayed on polar stereographic projections of the Northern and Southern Hemispheres. Examples of the product for the late Northern Hemisphere summer showed fire activity in Africa, Australia, Brazil, Canada, Siberia, and the United States.

3-Dimensional Images. NOAA meteorologists have developed a program to remap GOES infrared images to the perspective of a viewer at another location. Remapping an image of a hurricane to the perspective of an observer near the storm produces a dramatic 3-dimensional effect. These "3-D" images can be displayed in sequences that resemble films of the storm taken from a plane.

Rainfall. The Interactive Flash Flood Analyzer used by meteorologists to generate satellite derived precipitation estimates has been improved for use in connection with a tropical storm activity. During the fall of 1985, NOAA meteorologists produced precipitation estimates for Hurricanes Bob, Danny, Elena, and Gloria. A rainfall potential of 8 to 10 inches over eastern North Carolina and Virginia estimated from Gloria was indeed experienced, and rainfall of over 16 inches was estimated for Tropical Storm Isabell as it passed over Puerto Rico. During the year, the satellite precipitation-estimating operation expanded to worldwide coverage. NOAA meteorologists generated rainfall potentials for the tropical cyclone that caused many deaths and much destruction in Bangladesh. Also, the precipitation estimate messages formerly sent to the forecast offices via the National Weather Services Automation of Field Operations and Services system were changed to an area-alert proximity-alarm system. Now all nearby weather offices can receive estimates within their area of interest.

Input for National Meteorological Center (NMC) Models. Two new inputs or procedures were adopted for the NMC models, one relating to winds and one to moisture. A low-and high-level winds production run at 0600Z for the NMC models has been added, completing the 6-hourly cycle of satellite winds products for NMC model runs. This new data set will allow NMC to test and evaluate a new numerical forecast model.

The Satellite Moisture Analysis has been upgraded from pencil and paper procedures to an interactive system. Real-time infrared digital data from GOES are analyzed for moisture content at specific grid points. NOAA meteorologists are able to generate moisture profiles interactively over data-sparse areas for input to the numerical forecast models.

Food Shortage Alerts. The NOAA crop monitoring system is now operational over the African Sahel. Data from the NOAA-7 satellite and other data sources are combined to produce quantitative crop-status reports on a regular basis for use by USAID missions in the affected countries.

Transfer of the satellite technology has begun in Asia, where regular crop assessments are already being produced "in country" from meteorological data. Five scientists from two Southeast Asia countries have been trained in the use of satellite-acquired data, and image processing equipment is now available in Thailand.

Marine Assessment Application of Satellite Data. The application of remote sensing to marine assessment has been expanded to foreign countries. Studies are being conducted in the Philippine area and in the eastern Pacific off the coast of Peru and Ecuador. AVHRR data from NOAA-N satellites are being analyzed relative to fishery resources. A pilot project for Western Africa was initiated to apply remote sensing data to the management of fisheries.

Precipitation. Work is continuing on refinement of techniques for using data from operational satellites to estimate precipitation. For example, using GOES imagery, a study was completed of the characteristics of flash floods in the western United States; and, in an attempt to streamline the present method, the convective precipitation estimation technique has been automated.

AgRISTARS. NOAA participated in the development and operational demonstration of interactive, satellite-derived, precipitation estimation techniques for monitoring rainfall over such significant crop-growing regions of the world as the United States, the U.S.S.R., and South Africa.

Satellite Moisture Profiles. An evaluation was completed of relative humidity and mixing ratio profiles determined by two different satellite methods. One method uses GOES cloud imagery to describe vertical moisture profiles. The second method, TOVS, uses a 15-channel algorithm developed for use with data from polar orbiting satellites. Although the accuracies of both methods are inferior to those of moisture profiles obtained from surface-launched rawinsondes, the methods provide useful input into forecast models whose domain includes large oceanic areas. An advantage of the TOVS method is that it is fully automated and can be applied globally; however, an accompanying disadvantage is that moisture determinations can only be made in clear and partly cloudy areas.

Turbulence. A study of atmospheric turbulence showed that, in addition to the signatures turbulence displays in visible and infrared satellite imagery, turbulence can be indicated by the 6.7-micrometer water vapor channel of the GOES satellite. Examination of 100 cases in which there was an increase in the 6.7-micrometer channel brightness temperature (darker gray scale) as a function of time showed that over 80 percent of these cases had reports of moderate to severe turbulence with them. Thus, the water vapor channel can also be useful in diagnosing areas of probable turbulence for commercial and military jets.

Fisheries. Marine scientists in the Northeast Fisheries Center employed data from the Advanced High Resolution Radiometer of the NOAA polar-orbiting satellite to determine the location of thermal fronts in the ocean off the northeastern U.S. coast. Variations in the frontal positions were compared with sightings of beaked whales, and strong correlation was found between the whale sightings and an oceanic feature called the shelf/slope water front. These results were similar to those from a Center study showing greater abundance of short-finned squid in the proximity of the shelf/slope water front, thereby demonstrating the utility of remotely sensed thermal data in determination of the non-random distribution of beaked whales with respect to a presumed prey species (squid).

Through the Northeast Area Remote Sensing System (NEARSS) Association, the Northeast

Fisheries Center has joined a regional community of federal, academic, and private research institutions to improve the timely acquisition and availability of satellite remote sensing data, and to promote synergistic use of regional resources and expertise in developing research applications of remotely sensed data. The Association had established a regional telecommunications network for distribution of digital satellite data and products among participating organizations. Individual investigators access the data over the network using a relatively inexpensive NEARSS terminal, or compatible computer, which can also be used as an independent work station for analyses of the data. The hub of the NEARSS network is the Oceanographic Remote Sensing Laboratory at the University of Rhode Island, where digital satellite data are processed and archived for dissemination over the NEARSS network. The Laboratory is a cooperative development effort involving the University of Rhode Island and the Northeast Fisheries Center.

The Northeast Fisheries Center and the Oak Ridge National Laboratory of the Department of Energy continued working together on the first phase of the Coastal Habitat Assessment Research and Mensuration program. The first phase of this program is to inventory coastal and estuarine wetland degradation from North Carolina to Maine. Its objective is to develop a standardized protocol for comparing scenes from different geographic areas at different times and to validate the protocol with ground truth information.

The National Marine Mammal Laboratory used satellite imagery together with satellite-based ice forecasts from the National Weather Service to set up sampling plans and vessels transects for two separate research programs. They are a cooperative U.S.-U.S.S.R. walrus and ice seal study, and a bowhead whale study in the western Beaufort Sea.

Other Uses of Satellites

International Activities

Coordination of Geostationary Meteorological Satellites. In May 1985, a group of representatives from the European Space Agency, Japan, the U.S.S.R., India, the World Meteorological Organization, and the United States met in Tokyo, Japan. Highlights of the meeting included determining an acceptable method for assigning data collection system resources to support new programs such as the Automated Shipboard Aerological Program.

ARGOS. The ARGOS Data Collection and Location System (DCLS), provided by France, operates on the present NOAA polar-orbiting spacecraft. Of more than 750 active platforms operated by organizations from 17 countries, 70 percent require location calculations and 10 percent disseminate data via the Global Telecommunications System. Fourteen countries, including the United States, participated as members of the 1985 joint tariff agreement to use ARGOS DCLS during 1986. This agreement provides reduced data processing costs for all participants.

United States-Spain Joint Committee for Scientific and Technical Cooperation. A group of about 15 scientists, including six from NOAA, participated in a joint United States-Spain Workshop, held in the Canary Islands on September 18-26, 1985. The purpose of the workshop was to document Spanish pelagic fisheries resources of the Canary Islands and northwest Africa, and to review state-of-the-art remote sensing systems and products, that might be of economic benefit and importance to applied fisheries research. Tuna, sardine, and cephalopod (octopus, squid) pelagic fisheries were discussed. Results of the workshop will be published in a 3-year plan entitled, "Canary Island Based Fisheries and Remote Sensing Applications," to be prepared under the direction of the United States-Spain Joint Committee for Science and Technological Cooperation.

Training for Foreigners. NOAA conducts training internally and participates in external training seminars and workshops in order to improve the quality and exchange of satellite data and to contribute to cooperative research activities. During 1985, 14 foreign nationals from eight countries were trained in such areas as applications of meteorological satellite data, management of oceanographic and climatological data, and agroclimatic impact assessments. In addition, NOAA specialists lectured at and supported international workshops in the United Nations and the World Meteorological Organization on topics such as satellite-data applications, precipitation estimation, and climate data management and user services.

International Radio Regulations. In 1985, several meetings took place under the aegis of the International Telecommunication Union concerning the International Radio Consultative Committee's development of technical recommendations for space communications. The National Telecommunications and Information Administration (NTIA) participated in all these activities.

World Radio Conference on Space Communications. The prominent issues of the space conference were to guarantee equitable access to the geostationary satellite orbit and to incorporate results of the Region 2 Broadcasting Satellite Conference held in 1983 into the Radio Regulations.

During 1985, NTIA led government agencies in preparations for the two-part 1985 and 1988 World Adminstrative Radio Conference for space services (Space WARC). NTIA coordinated the development of proposed positions and strategies of the executive branch agencies for use in subsequent Space WARC negotiations, and played a key role in the first session of the conference, conducted during August and September 1985.

NTIA also expanded the capabilities of its computer-based model for analyzing orbit and spectrum use, the Geostationary Satellite Orbit Anaysis Program, to include modeling uplink power levels for Earth stations of the same network, modeling multiple antennas for each satellite, modeling multiple antennas for each Earth station, improving the user-friendliness of input data requirements, and improving output data reports. This, and other NTIA-developed automated models, were useful before and during the Space WARC to analyze various orbit and spectrum sharing scenarios.

The principal objective of the United States in this area is to avoid acceptance by the Conference of any form of rigid a priori planning of space services and associated frequency bands. An objective of equal importance is for the United States to maintain maximum flexibility in operating its present space communications systems and in developing its future space systems. Many developing nations prefer some sort of a priori planning, such as the firm allotment of spectrum space, even if it is not needed immediately. They perceive that the geostationary satellite orbit resource will soon be allocated to such a degree that their opportunity to use it in the future will be pre-empted. The U.S. view is that continuing advancements in technological development will be sufficient to offset the increase in demand, thus preventing actual saturation of the resource, and that only a flexible approach to satellite development and implementation can stimulate the necessary technological advances.

The Conference concluded that equitable access could be addressed with a dual planning approach that would entail an allotment plan and improved procedures and would apply only to fixed satellite service in specified bands. Unplanned bands and services would use the present procedure. The allotment plan was adopted for use in the "expansion bands" at 4/6 GHz and 11 to 12/14 GHz. These bands are not presently used by the U.S. for fixed-satellite services. The improved procedures, which include multilateral planning, were adopted for the conventional portions of those bands. Further, the first session of the Conference considered the provisions in the 1983 plan on broadcast satellites from the Region 2 Regional Administrative Radio Conference. After much debate, the Conference adopted and incorporated those provisions into appendixes 30 and 30A of the Radio Regulations. Because of the deadlock caused by the continuing insistence of certain Administrations on a priori planning in all frequency bands allocated to fixed satellite service, much work remains to be done in the intersessional period or at the second session in 1988. The United States must pay close attention to these activities to ensure that a sound basis exists for the decisions of the second session.

COMSAT Corporation. In cooperation with the Department of State and the Federal Communications Commission, NTIA monitors the activities of the Communications Satellite Corporation (COMSAT) in COMSAT's capacity as the U.S. signatory to the International Telecommunications Satellite Organization (INTELSAT) and the International Maritime Satellite Organization (INMARSAT). In November 1984, the President determined that international communications satellite systems separate from INTELSAT were required in the national interest, subject to certain limitations. These satellite systems are limited to customized services with long-term lease or sale of space-segment capacity for data, video, and other communications that are not interconnected to public switched-messages networks. These limitations ensure that there will be no significant economic harm to INTELSAT, while providing more customer options and a more efficient market for customized services.

NTIA, working with the State Department, issued in February 1985 a Senior Interagency Group White Paper detailing Executive branch policy. The Paper was transmitted to the Federal Communications Commission, along with recommendations that would restrict the systems so as to satisfy U.S. international obligations. The recommended restrictions require applicant systems to conclude operating agreements with one or more foreign correspondents and to complete consultation requirements with INTELSAT before the FCC will grant final authorization. NTIA will monitor the consultations with the INTELSAT Board of Governors and Assembly of Parties called for under Article XIV(d) of the INTELSAT Agreement.

Geodesy

IRIS Earth Orientation Monitoring Service. NOAA's National Geodetic Survey (NGS) continued to operate the two POLARIS (Polar-motion Analysis by Radio Interferometric Surveying) Very Long Baseline Interferometric (VLBI) observatories and to serve as the operational center for the International Radio Interferometric Surveying

(IRIS) Earth Orientation Monitoring Service (EOMS) throughout 1985. IRIS EOMS produced, at 5 day intervals, polar motion values with accuracies of 1 to 2 milliseconds of arc and Universal Time from 0.05 to 0.10 milliseconds. In addition, beginning in April, a special series of daily observations produced Universal Time values accurate to 0.01 milliseconds. The IRIS EOMS now produces an Earth-orientation time series that is the most accurate, and has the highest temporal resolution and the lowest operating cost of all the services in operation, and that will play a central role in the new international service planned to replace the Bureau International de l'Heure and International Polar Motion Service, beginning January 1988. The joint special study group of the International Astronomical Union and International Union of Geodesy and Geophysics, charged with planning the new service, recommended that the new Conventional Celestial Reference System be defined by an appropriate catalog of radio sources, rather than by the stars.

Errors in the current nutation series, revealed by IRIS VLBI observations suggest that Earth's core is slightly more elliptical than the value calculated assuming hydrostatic equilibrium; namely, that it is flattened by approximately 0.5 kilometers more than expected. The North America-Europe baseline lengths estimated from IRIS observations are increasing 1 to 2 centimeters per year, which is consistent with the expected relative motions of the tectonic plates.

Dynamic Global Positioning System (GPS). The National Geodetic Survey (NGS) has begun development of dynamic GPS techniques able to attain geodetic quality (10-cm) positioning of moving instrument platforms, including ground vehicles, ships, and aircraft. The first successful test of the dynamic phase-differencing technique, using TI-4100 GPS receivers, was conducted jointly with NASA's Wallops Flight Facility in August 1985.

An airplane carrying a GPS receiver and a laser altimeter flew over Chincoteague Bay. The GPS and laser altimeter height profiles obtained agreed with an RMS difference of only about 10 cm. Additional flights are planned to test the use of dynamic GPS positioning for photogrammetric mapping operations.

Satellite Altimetry. The launch of the U.S. Navy altimeter satellite, GEOSAT, in March 1985 ushered in a new era for geodesy and physical oceanography. Satellite altimetry has been shown to be one of the most versatile and useful techniques for ocean remote sensing and is considered to be a critical part of global oceanographic research programs. By measuring the shape of the ocean surface, an altimeter provides information on the geoid, circulation, and sea level variability that cannot be obtained any other way. GEOSAT represents the first altimeter satellite since the abbreviated SEASAT mission in 1978, and the only such satellite during this decade.

Because the GEOSAT data are classified, NGS has established a dedicated processing facility at the Johns Hopkins Applied Physics Laboratory, where raw data are downlinked and archived. Here, the altimeter profiles are analyzed to produce unclassified information available to the oceanographic research community. Anticipated products are time series of sea level in the equatorial Pacific, global mesoscale eddy statistics, improved tide models, surface circulation in regions such as the Gulf of Mexico, and measurements of wind speed and wave height. These products will contribute significantly to established national science programs. An example is the Tropical Ocean Global Atmosphere project, a 10-year experiment to investigate relationships between the equatorial oceans and global climate anomalies. Operations at the NGS GEOSAT facility began in September 1985, and will continue throughout the lifetime of the satellite, possibly as long as three years.

Photogrammetry

Large Format Camera (LFC). LFC, a state-of-the-art mapping camera, performed flawlessly on its first flight aboard the Space Shuttle Challenger from October 6 through 12, 1984. NOAA scientists directed the daily photographic coverage and manned the Payload Operations Control Center. Over 2,300 photographs, each 9 x 18 inches, were obtained for a portion of over 250 international investigator sites requested for coverage. Special stereophotography collected for NOAA included U.S. coastal regions, oblique photography of Hurricane Josephine, and night photography of lightning and urban areas. Experiments, including aerotriangulation, map compilation, and a variety of remote sensing applications, are now being conducted within the U.S. scientific community and several other nations.

Space and Atmospheric Research

First Space-Made Product Sold. The first sales of a product manufactured in space were announced on July 17, 1985, by the Commerce Department's National Bureau of Standards (NBS). Billions of tiny polystyrene spheres made aboard a NASA Space Shuttle flight are being offered as an NBS standard reference material. They will be used to improve microscopic measurements made in electronics, medicine, and other areas of high technology.

The spheres, each of which is 10 micrometers (1/2,500th of an inch) in diameter, were produced aboard the Space Shuttle Challenger, using a chemical process developed for NASA by Lehigh University. When produced in a low-gravity environment, the polystyrene spheres grow uniformly in size and shape. The spheres will be an important measurement reference material for producers of finely ground powder products such as paint pigments, inks, toners, chemicals, and other powdered material like flour and cosmetics, as well as for technologists who monitor environmental particulate pollution from industrial and chemical plants. The spheres will also be useful to medical researchers who calibrate instruments to count blood cells and measure their shape, and to medical personnel who perform a wide variety of diagnostic measurements. Morever, the spheres can be used by manufacturers for reference purposes in producing and distributing secondary measurement standards.

Network Protocols. The National Bureau of Standards is working with COMSAT in a research project to test and evaluate the performance of computer network protocols over satellite networks. Results of this collaborative research are helping to advance development of network products that implement Open Systems Interconnection (OSI) and enable different manufacturers' products to be interconnected using a variety of communications methods. Data collected and analyzed in a series of NBS/COMSAT experiments showed that technical modifications to one OSI standard would result in more efficient data transmissions. Voluntary standards groups developing the OSI standards have adopted these modifications. A second series of experiments is testing additional methods to achieve better performance and reduce delays in data transmission when network protocols are used in the satellite environment.

Properties of Heavy Lift Balloons. This project is sponsored by the Balloon Projects Branch of NASA. It is part of a continuing investigation by NASA to determine the cause of failure of helium-filled heavy-lift balloons in which the helium is contained by low-density polyethylene film. These balloons are used to lift instrument payloads of up to 5,000 pounds to altitudes of over 120,000 feet for various statospheric and astrophysical research projects. Since 1980, there have been increased incidences of catastrophic failures during ascent at 40,000 foot to 60,000 foot altitudes where the ambient temperature is about $-700°C$. Among the possible causes of failure are changes in the mechanical properties of the films used in the balloons' construction. At NASA's request, NBS scientists have investigated various aspects of the molecular structure, morphology, and mechanical properties of several types of polyethylene films used before and since 1980. NASA is using the results as a basis for establishing new acceptance criteria for films to be used in construction of future balloons.

Fiber Reinforced Composites. NASA's Langley Research Center, the University of Illinois, and several manufacturers of composites are cooperating with NBS to study the basic failure mechanisms in composites and to develop tests that measure the resistance of composites to crack growth. Results indicate that a major weakness in many thermoplastic composites is that poor fiber-polymer bonding, significantly reduces the composites' resistance to crack growth. Another activity in this cooperative project was refinement of the general correlation between polymer toughness and composite fracture energy established earlier in the project. The data from the activities provide valuable guidelines for designing and fabricating new materials.

Space Station Robotics. NASA's Goddard Space Flight Center plays a major role in the Space Station project. This role includes analyses, definition, and development of customer servicing equipment for the Station. Customer servicing functions will consist of in-orbit recovery, repair, maintenance, assembly, resupply, checkout, and upgrade of customer hardware such as satellites, platforms, attached payloads, and customer equipment in or on the Space Station. Many of these services will be performed robotically. NBS is currently funded by NASA to develop a model of general rules and methodologies for evaluation of robotic techniques to support these servicing activities. NBS will also perform "proof of concept" robotic experiments and supply the resulting engineering data to NASA.

Spectrometer Calibration. NBS performed extensive calibration work for NASA with the Space Telescope Optical Simulator (STOS), which was designed and constructed by the Martin Marietta Aerospace Company. Devised to calibrate the Faint Object Spectrograph, an instrument on the Hubble Space Telescope, STOS provides optical emissions which simulate expected observations by the orbiting telescope.

Besides providing the above measurement services and standards, NBS calibrated 11 transfer standard photodiode detectors for space science groups in the past year to establish a radiometric base for their measurement programs. In addition, the NBS-SURF spectrometer calibration facility was used for a total of 36 weeks by various teams of space scientists engaged in high-accuracy solar, stellar, and atmospheric studies.

Ozone Concentration Measurement. A new NBS high-accuracy ultraviolet, dual-beam ozone photometer has been installed at NASA as the national ozone standard. The instrument is used routinely to calibrate ozone monitoring instruments throughout the stratospheric ozone observation programs of NOAA and NASA.

Stellar Spectroscopy. NBS scientists are pursuing a major program to measure surface magnetic fields on stars cooler than the Sun. They have recently detected for the first time the presence of strong magnetic fields on the surface of a flare star, Ad Leonis. Using observations made by the 4-meter Fourier Transform Spectrometer located at Kitt Peak National Observatory near Tucson, they detected the presence of magnetic fields with an average strength of 3,800 gauss in active regions outside dark spots. This value of the field strength is interesting because the resulting pressure of the magnetic field equals the gas pressure at the deepest layers of the star that are visible optically. These findings should aid in understanding stellar activity such as flares, spots, and hot coronae on some stars.

Antarctic Studies. The results of research on the application of AVHRR data for the study of katabatic winds (descending motion causing a change in atmospheric pressure) in Antarctica show that the satellite data can supply much information on the temperature changes that occur during this meteorological phenomenon. The accompanying image is an example of what an event looks like in the satellite data and illustrates the temperature changes that accompany warming of air as it flows from higher to lower elevation. Temperature increases were found to range from 20 to 30°K above the ambient temperatures.

Mesoscale and Severe Storms. NOAA continues its support of severe storm studies by Dr. Fujita at the Unversity of Chicago. Emphasis is now on microbursts – the small scale convective downdrafts that can produce strong horizontal wind shear so hazardous for aircraft during takeoffs and landings. Although the phenomenon has been identified and described by Fujita, the main problem is inability to detect this shear remotely, let alone to anticipate its occurrence. A study is under way to investigate meteorological events leading to the Dallas microburst in August 1985 in which Delta Air Lines flight 191 crashed, killing 125 persons. During the summer of 1986, a field project will seek information on microbursts in very wet environments.

Sea Ice. Infrared images from NOAA polar-orbiting satellites were used to map sea ice conditions in the eastern Bering Sea and Bering Strait during cloud-free periods in the winter of 1985, as part of the Arctic Polynya Experiment. This work was funded jointly by the Office of Naval Research, Atlantic Richfield, and NOAA. The satellite im-

Image from Advanced Very High Resolution Radiometer (AVHRR) on NOAA meteorological satellite showing temperature changes in Antarctica due to katabatic process.

ages were used in conjunction with drifting satellite-transmitting buoys to investigate mesoscale strain of pack ice floes as they are pushed by wind and current around headlands and islands. Eventually the results will be incorporated into sea ice forecasting models to aid marine transportation in icy waters.

Solar Wind-Magnetosphere-Ionosphere Coupling. In cooperation with and support of DOD, industry, and the international scientific community, NOAA's National Geophysical Data Center has embarked on a program to improve the Nation's ability to forecast and specify the near-Earth space environment. A new, mid-and high-latitude model of the ionosphere was developed. Initial correlation studies of the solar winds variability with specific ionospheric currents and fields in the polar regions show promising results. Discussions incorporating solar atmospheric models, solar wind models, and thermospheric, neutral atmospheric models have been conducted with scientists from DOD, NOAA, and the National Center for Atmospheric Research (NCAR).

Solar Storms. An operational "shock wave" algorithm was developed by NOAA in which real-time observations of radio bursts from solar flares, as detected by the USAF Radio Solar Telescope Network, are used to calculate the time of arrival on Earth of the shock wave created by the flare. Impact of the shock wave on the Earth's magnetosphere can initiate a geomagnetic storm when the dynamic pressure of the solar wind, and the polarity of the interplanetary magnetic field are appropriate.

Aeronautical Programs

New Products for the National Airspace System (NAS). In response to requirements of the Federal

Aviation Administration, NOAA continued to produce aeronautical charts and related products for navigation in, and control of, the U.S. NAS. To support this effort, the National Ocean Service developed new aeronautical prototype products during 1985. A Visual Flight Rules (VFR) Flyway Planning Chart was developed and distributed to assist VFR aircraft in arriving, departing, and transiting congested terminal areas throughout the United States. Also designed and distributed to the public for evaluation were a prototype chart for use in high-altitude flight under the Instrument Flight Rules and Radio Navigation charts for use in area navigation. The results of the evaluation were favorable and may lead to a redesign of all Instrument Flight Rules en route charts.

Department of Energy

For nearly 30 years, the Department of Energy (DOE) and its predecessor organizations have supported the design of advanced nuclear systems for generating power in space. This effort has resulted in the development and delivery of a number of radioisotope thermoelectric power systems that have proved to be safe and highly reliable. They are the SNAP-3A, SNAP-9A, SNAP-19, and SNAP-27, members of the Systems for Nuclear Auxiliary Power series; MultiHundred Watt Radioisotope Thermoelectric Generators (MHW-RTG); and the High Performance Generator (HPG) Mod-3 RTG. These systems are essential for the success of NASA and DOD space missions and other special applications. Specifically, they have provided electrical energy for NASA's Pioneer, Viking, and Voyager missions, as well as earlier Earth orbital and lunar missions. Moreover, newly designed General Purpose Heat Source (GPHS) RTG's have been developed and produced as essential power systems for the Galileo and Ulysses spacecraft. Space power systems providing electrical energy far surpassing the practical range of RTG's, spanning 1 to 100-plus kilowatts, are also in initial stages of development. Together with the advanced modular RTG, these radioisotopic or reactor-powered systems are directed toward NASA and DOD mission requirements for the 1990's.

Space Nuclear Power Systems

Two types of nuclear systems have been used to generate electricity for spacecraft. First is the Radioisotope Thermoelectric Generator (RTG), the nuclear power source used most often by the United States. It is a static device which converts the heat from decaying radioisotope plutonium-238 directly into electricity by means of the Seebeck effect in thermocouples. Thus, there are only two functional parts of an RTG: a heat source and a thermoelectric converter. The second type of system which can be used on spacecraft to generate electricity is the nuclear reactor. Like RTG's, reactor power plants are basically heat engines that convert heat from the fissioning of radioactive materials, uranium-235 in this case, into electricity through either static (thermoelectric element) or dynamic (rotary shaft) subsystems. DOE's program in 1985 consisted of two major projects: the static outerplanetary RTG project, including production and testing of RTG's for NASA's Galileo spacecraft mission to Jupiter and the Ulysses (formerly International Solar Polar Mission) spacecraft mission to study the Sun; and the SP-100 space reactor technology program. Figure 1 depicts the GPHS-RTG. Figure 2 is an enlargement of the GPHS-RTG silicon-germanium unicouple.

Radioisotope Thermoelectric Generator

The Atomic Energy Commission, predecessor to the Department of Energy, began developing RTG power systems in 1956. Since 1961, the United States has used 34 RTG's as electrical power supply systems in 19 space systems, including navigation and communication satellites launched by DOD, and scientific spacecraft launched by NASA. These RTG's encompass six advanced design concepts spanning beginning-of-mission power levels ranging from 2.7 to 159.2 watts of electricity. Throughout this period, the efficiencies of thermoelectric elements have improved substantially. All the RTG's from SNAP-3A to the MHW exceeded their design requirements by providing power beyond their planned lifetimes. RTG's have proved to be rugged, dependable power supplies, independent of the external environment. In order to optimize power density and safety, DOE is continuing to support studies on RTG design, heat source materials, and thermoelectric materials.

In 1985, assembly and space acceptance testing were completed for four GPHS-RTG's to be used on the Galileo and Ulysses missions. The testing covered vibration, thermal vacuum performance, mass properties, magnetics, and radiation dose rate measurements. The 55.5 kilogram GPHS-RTG, using advanced silicon-germanium thermoelectrics technology to convert heat to electrical energy, is designed to provide a minimum of 285 watts of electricity with a fuel loading of 4410 thermal watts. Life testing of the GPHS-RTG qualifica-

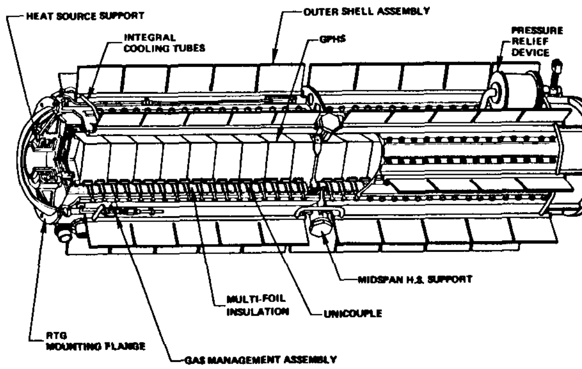


Figure 1. The General-Purpose Heat Source Radioisotope Thermoelectric Generator (GPHS-RTG).

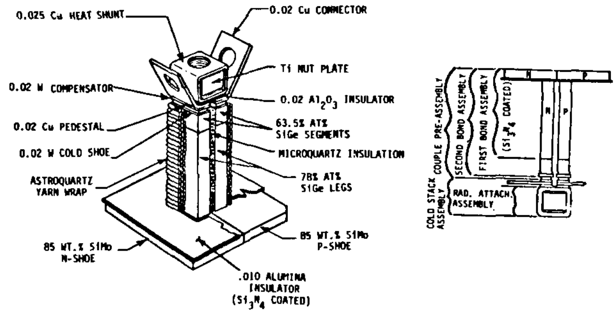


Figure 2. The GPHS-RTG Silicon Germanium Unicouple.

tion unit under simulated space conditions continued throughout 1985. This testing demonstrated that the GPHS-RTG will exceed NASA's requirements. Assembly of 134 lightweight radioisotope heater units also was completed in 1985. Generating approximately one watt each, these units are required to keep sensitive instruments warm on the Galileo spacecraft.

Safety efforts included completion of three safety verification tests of full-up GPHS fueled modules used to power GPHS-RTG's. In addition, impact tests of full-up fueled modules were conducted, as well as explosion overpressure tests of simulant-fueled modules and RTG components required for the final safety analysis reports of the Galileo and Ulysses missions. Reports for GPHS-RTG's and the lightweight radioisotope heater units were completed and published in 1985.

The SP-100 Space Reactor Program

The SP-100 Program was initiated in 1983 as a cooperative effort among DOE, DOD, and NASA. Its purpose is to develop and demonstrate technology for space reactor power systems that will enhance a wide variety of emerging civilian and military missions whose requirements cannot be met by power sources in the current generation.

The three phases of the SP-100 Program are assessment and advancement of technology, engineering system development and testing on the ground, and flight qualification. The first phase of the program, completed in 1985, focused on technology for space nuclear reactors in the power range of tens of kilowatts to 1,000 kWe (1 MWe). On August 1, 1985, during the second phase of the program, the fast-reactor thermoelectric power-conversion concept was selected for further engineering development and demonstration testing on the ground, at a power level of 300 kWe. Figure 3 depicts a reactor thermoelectric concept.

During 1985, important technical objectives related to the power system concept selected for the SP-100 were achieved. Fabrication technologies for the refractory metals and advanced fuel of the selected concept were used; irradiation testing of high-temperature refractory metals and fuel cladding was conducted with encouraging results; all major safety issues were identified and analyzed; and safety guidelines were established to ensure protection of the public and the environment under both normal and accident conditions.

In October, a Memorandum of Agreement among DOE, DOD, and NASA formally initiated Phase II of the SP-100 Program. Phase II differs from Phase I organizationally in that each participating agency is responsible for a specific element of the program instead of sharing responsibilities of all elements. Flight demonstration of a 300-kWe nuclear-electric power system scheduled for the early 1990's as the reference mission for SP-100 will help focus the Phase II efforts.

Through the Air Force, DOD will coordinate the overall direction of the program, analyze the SP-100 military mission and define the military requirements. DOE will develop and test the ground engineering system, and NASA will develop SP-100 non-nuclear technology and analyze and define the requirements for civil uses of the SP-100.

As part of its responsibility for developing the ground engineering system, DOE will manage the designing of a reference space reactor power system consistent with the concept selection of August 1, 1985. Included will be assembly, performance, and safety testing at a DOE site. The initial DOE Phase II efforts have concentrated on selecting the system developer and the test site. The system developer, to be selected in mid 1986, will design and build the power system and direct the test program.

Plans were initiated in 1985 for increasing the capacity of the space reactor beyond the 1 MWe

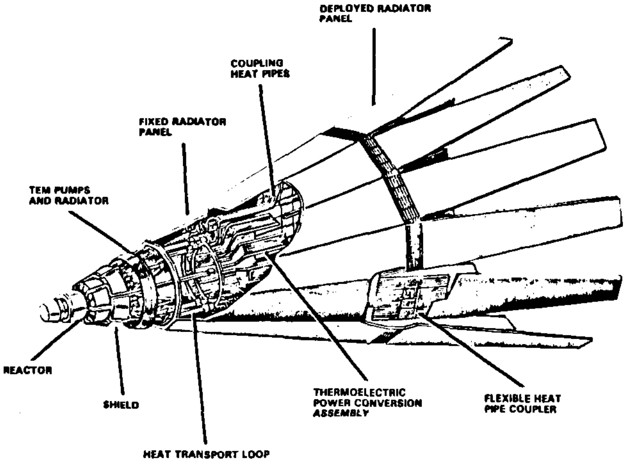


Figure 3. Thermoelectric concept.

power level into the multimegawatt power range for both continuous and pulsed power applications. Power system concepts were identified and will be evaluated in 1986 before selection of the concepts to be developed and tested. The development of space reactor power systems in the multimegawatt power range will require significant advances and breakthroughs in several technological areas.

Nuclear Test Detection

The national capability to detect and monitor nuclear testing, both inside and outside Earth's atmosphere, is being supported by DOE through the design, development, and production of spaceborne nuclear detection systems. A variety of satellite-based optical and radiation detectors provided by DOE will permit worldwide surveillance of nuclear testing and will verify whether tests comply with the Limited Test Ban and Nonproliferation Treaties. Nuclear detection systems supplied by DOE are flown as secondary payloads aboard DOD and NASA spacecraft.

The DOE national laboratories are responsible for designing, fabricating, and testing detector instrumentation consisting of sensing elements, the elements' electronic circuitry, and downlink telemetry logic. The objective of this instrumentation work is to continue improvements in sensitivity, coverage, and data processing techniques to enable the detection systems to better distinguish nuclear events from background signals, prevent false alarms, and detect unusual events. In 1985, DOE also continued its program to improve radiation hardening for its spaceborne detector systems.

Department of the Interior

As caretaker for more than two million square kilometers of public lands, the U.S. Department of the Interior is responsible for managing, conserving, and developing natural resources on this element of the national domain. The Department frequently relies on data acquired by remote sensing devices for inventorying, managing, and monitoring these vast, often inaccessible lands. Bureaus and agencies of the Department participating in remote sensing studies during 1985 included the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Mines, Bureau of Reclamation, National Park Service, and U.S. Geological Survey.

Remotely Sensed Data Acquisition and Processing

The Earth Resources Observation System (EROS) Data Center of the U.S. Geological Survey (USGS) continued to process, archive, and distribute Landsat data to users for the National Oceanic and Atmospheric Administration (NOAA). During 1985, 42,000 Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) images were added to the archive, bringing the total to 660,000 images. Approximately 46,000 film and digital products were generated and distributed to users worldwide. The EROS Data Center completed initial modifications required to support the transition of Landsat operations and data marketing and sales to the commercial Earth Observation Satellite Company (EOSAT). This transition began when a contract was signed between EOSAT and the Department of Commerce on September 27, 1985.

Contracting for photography for the National High-Altitude Photography Program (NHAP) was completed in 1985 at an overall cost of $18.9 million, covering the years 1980 through 1985. The initial phase (NHAP I) was begun in 1980 by participating federal agencies for the purpose of acquiring 1:80,000-scale black and white and 1:58,000-scale color-infrared photographs of the conterminous United States during the nongrowing (leaf-off) season. The acquisition of photographs was contracted to commercial aerial survey firms. Photographs covering about 2,700,000 square miles, or about 87 percent of the conterminous United States, have been acquired and are available from USGS and the U.S. Department of Agriculture for distribution to public and private users. It is anticipated that all photographic acquisition for NHAP I will be completed by the end of 1986.

The second major phase (NHAP II) began in 1985 as a 5-year plan to acquire the same types of photographs of the conterminous United States, but with two differences from NHAP I: imaging is to occur during the growing (leaf-on) season instead of the nongrowing season, and the work units to be contracted for are complete states rather than 1-degree blocks.

The USGS Side-Looking Airborne Radar (SLAR) program continued in 1985. The program began in 1980 with the Congressional mandate to acquire SLAR images for topographic and geological mapping and geological resource surveys in promising areas. During 1985, a contract was awarded to acquire data on approximately 208,000 square miles in the conterminous United States. SLAR data for more than 735,000 square miles in the conterminous United States and Alaska have been acquired, or contracted for acquisition, from 1980 through 1985. Data are available as image strips, 1° by 2° mosaics, and, for selected areas, computer-compatible tapes. Acquisition areas are selected on the basis of recommendations by State geologists, private industry, and USGS scientists.

One of the primary cartographic applications of SLAR data is in the preparation of image maps of persistently cloud-covered areas, such as Alaska, where conventional aerial photographs are very difficult to obtain. A set of 1:250,000-scale radar-image products was prepared by USGS in 1985 of the Ugashik, Alaska, quadrangle to provide comparative images from both real, and synthetic-aperture SLAR systems.

In 1985, USGS published an experimental printing of a combined geologic map and radar image of northeastern West Virginia for use in evaluating the use of radar images in geologic and hazards mapping in the folded and thrust-faulted valley and ridge portions of the Appalachian Mountains. This combination of geologic data and high-resolution radar images of intensely folded and faulted terrain provides a unique map base for correlating similar geologic structures and identifying anomalous geologic trends.

Digital Data Processing

Software Development

The USGS is cooperating with NASA's Goddard Space Flight Center to develop the Land Analysis System (LAS) software package. LAS contains comprehensive image processing and geographic information system software, for processing both raster and vector data. A major objective of the LAS project is to develop transportable software that can be used on a variety of computers, including a combination of a minicomputer and microcomputer work stations, to take advantage of distributed processing technology. Major software programs were released in 1985, including applications software, enhanced catalog manager functions, and improved raster display management software. A limited effort is now underway to install selected software components in an operating system known as UNIX.

During 1985, the National Park Services (NPS), in cooperation with NASA's National Space Technology Laboratories and the USGS, continued to convert the Earth Resources Laboratory Applications Software (ELAS) to the UNIX operating system. The NPS and several other Federal and non-Federal agencies use ELAS to process and classify multispectral data from either satellite or aircraft platforms. This software conversion will enable NPS and other users to run ELAS on low-cost computer hardware configurations, including graphics work stations.

Image Processing Workstations

The Remote Information Processing System (RIPS) developed by the USGS is now operational as a work station for demonstration and training, and for use in small-scale applications of image processing and spatial-data handling. The baseline software system was modified in 1985 to provide additional capabilities, but existing hardware configurations will undergo only limited new development. Development of a comprehensive image processing work station will continue, however, under the LAS effort.

The second RIPS Users Conference was held in 1985. Users from private industry, universities, and State and Federal agencies met to exchange information on the applications of RIPS and to define the products, services, hardware, and software needed to support low-cost microprocessor work stations that can process, analyze, and display remotely sensed and other types of spatial data.

Portion of a USGS Side-Looking Airborne Radar (SLAR) image covering part of the Mojave Desert west of Blythe, California. Prominent features include Interstate Highway 10 (bottom) and several mountain ranges, including the McCoy Mountains (right). Note the drainage pattern detail in the alluvial valleys between the mountain ranges.

Remote Sensing Applications

Renewable Resources

In 1985, the Bureau of Reclamation (BOR) expanded its use of aerial and satellite remote sensing to accomplish its mission goals. For example, an intensive environmental inventory was undertaken of an 1,800-square mile area which may be affected by the Garrison Diversion Unit of the Pick-Sloan Missouri Basin Project of North Dakota. Data interpreted from large-scale, color-infrared aerial photographs were entered into a digital geographic data base for statistical analysis and display. This activity will continue into 1986 and beyond. In another application, airborne video infrared images and Landsat TM images were used to update information on irrigated lands in the Newlands Project in Nevada. Information about changes in irrigated land use were entered into the geographic data base. Enlarged to 1:24,000 scale, Landsat TM data were also used to verify irrigation activity and inventory crop type.

The USGS Interim Land-Cover Mapping Project in Alaska resulted in production of six land-cover maps, corresponding to the Arctic, Dillingham, Fairbanks, Valdez, Mount Michelson, and Meade River 1:250,000-scale quadrangles. Landsat MSS data were combined with digital elevation data and field observations to produce the land-cover maps. Statistical summaries of land-cover types, which include percentage covered by class and total acres and hectares for both township and quadrangle, have been produced for each quadrangle.

NOAA's digital Advanced Very High Resolution Radiometer (AVHRR) data are used for mapping fire fuels in the Bureau of Land Management's (BLM) Initial Attack Management System. This system is designed to detect wildlife outbreaks and predict fire spread characteristics. Mapping was completed for California and Nevada during 1985. The procedures for mapping fire-fuel types using digital classification of AVHRR data are now considered operational. Sections of nine other western States remain to be mapped.

In a cooperative project between the Bureau of Indian Affairs (BIA) and USGS, Landsat TM color-composite images were evaluated as a source of information for assessing reservation resources. Landsat TM data were acquired to determine the best band combinations for color compositing and for manual interpretation at 1:100,000 scale. Training workshops were conducted at the Warm Springs and Yakima Reservations in 1985 to familiarize agency and reservation staff with the project and the potential uses of TM data. Specific inventorying and monitoring activities have been identified for which TM data are applicable. Strategies for using TM data have been defined and evaluated with regard to accuracy and timeliness of the interpretation, and a set of guidelines has been prepared to describe TM data acquisition, resource monitoring, and assessment procedures.

The BIA, USGS, and Michigan Technological University are analyzing Landsat TM data for detecting changes in forest stands, wetlands, and urbanization parameters in several study sites on the Upper Peninsula of Michigan. These data are being evaluated using a geographic information system to show changes caused by management activities. Results will demonstrate the extent to which Landsat TM data can be used to inventory natural resources for forest, range, and wetlands management.

In 1985, the NPS used Landsat TM data in combination with arc-second digital elevation data to develop digital data bases for 13 National Parks in Alaska. When completed, these digital data bases will be used in fire management, vegetation mapping and management, and many other resource management and planning applications in the Alaska parks.

For proper management of its forest lands, the U.S. Forest Service (USFS) must inventory timber types and volumes, usually with extensive field work. Through a cooperative USGS-USFS project, a new approach based upon Landsat MSS data and digital elevation data has been applied to inventory timber in the 2,200-square-mile Sierra National Forest of California. Forest types and densities were mapped to derive standing timber volume and basal area measurements. Twenty-five forest classes were mapped using Landsat MSS data stratified with digital elevation data. Seventy plot sites were selected randomly for field measurements to derive the volume of standing timber per acre. This information, coupled with acreage summaries by stratified class, will provide an accurate estimate of timber volume in the National Forest.

New applications involving NOAA AVHRR data have been developed in cooperation with the BLM, BIA, and the Nebraska Forest Service. The AVHRR data are integrated into a multi-layer digital data base and are used to capture time-series spectral change. Time-series analysis of AVHRR data for southwestern U.S. rangelands shows that biomass production and growth stage can be monitored. Biomass monitoring provides the range manager a method to assess growth and use, and the fire manager a method to monitor the onset of vegetation senescence (browning of the vegetation), when the probability of fire ignition increases. Research on methods to relate AVHRR data to actual fire occurrences is being conducted for the State of Nebraska. AVHRR data for Nebraska test sites for the 1981 and 1984 growing seasons have been compared with corresponding ground data to determine the herbaceous vegetation fuel condition, which is used in computing a fire-danger rating for the State.

Soils Mapping

In a cooperative project involving the BLM, the Soil Conservation Service, and the USGS, digital elevation and Landsat MSS data have been combined to test the concept of using alternative data sources for soils mapping. Digital data summaries of elevation category, steepness of slope, direction of slope, and greenness and brightness of vegetation are used with field observations to complete soil surveys of test areas in Nevada. Data are merged and analyzed to produce a soil pre-map of the project area showing terrain, landform, soils, and spectral data attributes.

Hydrology

Scientists at BOR are studying water quality using Landsat MSS and TM data and multispectral images acquired by aircraft. Monitoring has been completed on Blue Mesa Reservoir in Colorado, Lake Havasu and Lake Pleasant in Arizona, and Flaming Gorge Reservoir in Wyoming. Data from airborne multispectral scanners have been used to help define water seepage problems through and around the embankments of Deer Flat Dam in Idaho. The analysis helped field engineers to locate and identify some previously unknown seepage areas. In another project, high-resolution thermal-infrared images were used to observe nighttime roosting habits of Sand Hill Cranes on the Platte River in Nebraska. The technique provided data for studies on roosting preferences and an inventory of the number of birds at the site.

Data from the NOAA Electronically Scanned Microwave Radiometer are used in a USGS research project to map the water equivalent of snow in the Upper Colorado Basin. The project is designed to develop methods to predict water runoff that will assist in flood prevention and management. Five years of data are being correlated with ground measurements of snow pack and water runoff. Data from the winter of 1984-85 are being used to guide sampling teams in the field.

Geology

Geologic Mapping and Analysis. Based on five years of research and applications experience with a commercial non-imaging airborne spectrometer, an analytical approach based upon physical properties has been developed by the USGS and used to map and identify clay and carbonate minerals in a large mineralized area in Nevada. Data from NASA's experimental Airborne Imaging Spectrometer (AIS) are being analyzed in an effort to find similar applications. The AIS is the first of a new generation of imaging devices with 10-nanometer spectral resolution, and as many as 128 spectral channels. The increased spectral resolution should assist significantly in identifying a large number of minerals. Current research is concentrated on development of a method of analysis that will handle large volumes of data more effectively.

The USGS is evaluating the utility of data from Landsat's TM and NASA's Thermal Infrared Multispectral Scanner for locating disseminated gold deposits. These deposits are a prime exploration target for the mining industry in the United States. Current studies are focused on defining the physical properties of the deposits and on developing image-processing techniques to take advantage of the physical properties. A rare ammonia-feldspar, buddingtonite, has been identified at several of the known deposits. The ammonia in the feldspar produces distinct spectral characteristics that can be identified with NASA's AIS. Thus, the potential exists to use available data to distinguish a unique characteristic of disseminated gold deposits.

The USGS applied Landsat TM data as a basic geologic mapping tool to map and identify hydrothermally altered rocks in a sparsely vegetated heterogeneous geologic setting in the Drum Mountain, Utah; BLM Wilderness Study area in Nevada, and the San Carlos Indian Reservation, Arizona for BIA. Also, a small project was demonstrated for the government of Morocco. Concurrent Landsat TM and MSS data were geometrically corrected and digitally enhanced to generate products for field use and comparative application. Color-ratio-composite images of TM data were shown to be the most useful digital enhancements for distinguishing rock types dominated by calc-silicate minerals, gypsum, carbonates, and certain clay minerals. Comparison of enhanced TM and MSS images of other semiarid areas verified the significant contribution of TM data in mapping hydrothermal alteration and other lithologic variation.

Mine Development and Safety Monitoring. The Bureau of Mines (BOM) has demonstrated that digital Landsat data are effective in delineating geological structures, such as faults or sand channels, that cause ground control problems in underground mines. These geological structures are generally expressed on the ground surface as linear features defined by vegetation and topographic variations. Such features, called lineaments, are mapped and correlated with ground conditions in underground mines, producing a map that shows potential hazards in advance of future mining. Lineaments are determined from computer analysis of digital Landsat data. To expedite cross-checking of the relationship between plotted lineaments and ground control problems encountered in mines during routine operations, a computerized telecommunications process transmits information on mining status between individual mines and BOM's Denver Research Center. This interactive computer process for data analysis is being evaluated at selected coal mines. Preliminary results indicate that geologic lineaments closely coincide with roof-fall areas, especially where the lineaments intersect boundaries of sandstone channels at the mine horizon.

Geologic Studies in Antarctica. Digital mosaics of Landsat MSS images are specially processed to provide polar researchers with accurate synoptic views of land and ice features in selected regions of Antarctica. Spectral signatures and spectral ratios of soil and rock are sufficiently different from those of snow and ice to permit the preparation of maps showing rock-type classifications and detailed locations of rocky islands known as nunataks. Others maps show the location of blue ice, which contains most of the meteorites found in Antarctica.

Planetary Studies. NASA's Voyager spacecraft, launched in August and September of 1977, returned several thousand pictures of Jupiter, Saturn, and their satellites. Over 300 of these pictures form the basis of a geologic mapping program of three of Jupiter's satellites – Ganymede, Io, and Europa. The program, organized and managed by the USGS, includes mapping of 18 quadrangles by more than 40 investigators from various universities, research institutes, and government offices in the United States, England, Germany, and Italy. The mapping is generally done at a scale of 1:5,000,000 except for Io, where three maps are being produced at two scales, 1:1,000,000 and 1:2,000,000. During 1985, USGS scientists studying Io have shown, through computer simulation of basaltic volcanic eruptions, that temperatures of the eruptions on Io are similar to temperatures from sustained eruptions of basaltic lava flows on Earth. Many of the volcanic features on Io have previously been interpreted in terms of sulphur volcanism. Models based on basaltic lava flows, which are most common here on Earth, are now thought to better characterize volcanism on Io.

A new 1:15,000,000-scale geologic map of Mars is in the final stages of publication by the USGS. The map is divided into three sections, one for each of the western equatorial, eastern equatorial, and polar regions. The map, based on high-quality, high-resolution Viking images, shows greater detail than does the previously published 1:25,000,000-scale geologic map. It contains new geologic and stratigraphic information resulting from detailed studies of Martian geology by many investigators, and redefines and subdivides the previous chronostratigraphic system of Mars. It was jointly produced by USGS and university scientists in the United States and England.

Cartography

Satellite Image Mapping. The USGS has concentrated its image mapping production work for 1985 on refining procedures and specifications in order to develop a standard production system for image maps. Projects completed during the year used image data acquired by satellites using various types of sensors. Research which started with Landsat MSS and TM data continued this year with the addition of NOAA AVHRR data. A procedure was developed and tested to make 1:100,000 MSS color-infrared image mosaics of standard 1:1,000,000 quadrangles that meet national mapping standards. AVHRR images provide 1-kilometer resolution data, which can be used for large-area, small-scale products. An experimental image mosaic of the western United States was prepared at 1:4,000,000 scale by digitally mosaicking five AVHRR scenes. During 1985, digital image processing was completed for image maps from Landsat TM data at 1:100,000 scale for four standard 1° by 30′ quadrangles (Pahute Mesa and Cactus Flats, Nevada; and Kansas City and Olathe, Kansas); and from Landsat MSS data at 1:250,000 scale for four standard 1° by 2° quadrangles (Mariposa, California; Goldfield, Nevada; Roanoke, Virginia; and Denali National Park, Alaska). These maps will be published in 1986.

Research in 1985 implemented software for spatial filtering of image map products, compared cubic convolution interpolation with least squares restoration to resample Landsat images, improved digital processing to remove detector striping, and improved the color and contrast relationship between a digital display and the output product through color calibration research. In addition, geometric rectification studies improved the correction of relief displacements and increased the accuracy of ground-control-point selection through the use of video-map and image-overlay techniques.

Sonar Image Mapping. Over the past five years, the USGS and the British Institute of Oceanographic Sciences (IOS) have cooperated in a program to collect, process, and analyze sonar images of the ocean bottom. Side-scan sonar images have been collected by the GLORIA (Geological Long Range Inclined Asdic) system, which was designed, built, and is operated by IOS. GLORIA was first used in 1979 to collect analog sonar images for selected areas along the U.S. Atlantic coast. In 1982 the USGS and IOS collected GLORIA image data in the Gulf of Mexico, including digital data on

Enhanced sidescan sonar image acquired by the Geological Long Range Inclined Asdic (GLORIA) system of the Taney seamounts (submarine mountains). These seamounts (light-toned features) rise approximately 2,000 meters above the Pacific Ocean floor 280 kilometers southwest of San Francisco, and many contain calderas in their summits.

computer-compatible tapes. In 1984, GLORIA was used to collect sonar image data covering part of the newly declared Exclusive Economic Zone (EEZ) off the U.S. West Coast. Due to the increased volume of data collected and the high interest in the EEZ, software to process GLORIA digital data was refined, expanded, and made operational on the USGS Mini Image Processing System. Geologists have studied processed GLORIA data of the West Coast EEZ area to determine the value of a reconnaissance view of the ocean floor. So far, they have discovered over 50 submarine volcanoes, large landslides, fault scarps, and extensive meandering channels that were previously unknown. Data are being processed to generate 33 2° by 2° image mosaics of the West Coast data.

New data were collected during 1985 for most of the Gulf of Mexico and the extreme southern portion of the Atlantic Coast. Work also continues to process bathymetric and magnetic data recorded on navigation tapes. These data will be processed using surface-display software to create images that will be overlaid on the digital sonar image data.

Aerial Profiling of Terrain System. After successfully completing several map-testing and point-positioning projects, USGS has declared the Aerial Profiling of Terrain System (APTS) operational. As a precision airborne surveying system able to measure elevation profiles accurately, APTS is now undergoing a series of applications tests to determine its effectiveness and to optimize its performance.

In its first operational test, APTS is being used to help the State of Utah design a water drainage system to control the water level of the Great Salt Lake by diverting excess water to form a new lake 30 miles to the west. Accurate elevation profiles are needed to determine the potential shoreline, depth, and volume of the new lake, as well as where dikes will be required. In 1985, APTS completed 16 profiling missions over the Great Salt Lake Desert, obtaining 1,200 linear miles of profile data covering 1,400 square miles. This was a challenging project because of the hot, dry environmental conditions, and the large area surveyed. The profile data have been processed and final data have been provided to the State of Utah.

International Activity

The USGS conducted two international remote sensing workshops in 1985. One workshop, held at the EROS Data Center for 29 scientists from 18 countries, covered applications of Landsat data to geologic, hydrologic, and other resource assessment problems. Another, a three-week remote sensing workshop, was held in Beijing, People's Republic of China. Chinese scientists from the National Bureau of Surveying and Mapping received training from the USGS in the principles of remote sensing and applications of digital image processing techniques to resource monitoring and mapping.

In continuation of a cooperative agreement, BOR scientists visited Spain in 1985 to train Spanish scientists to use digital Landsat data analysis techniques in monitoring the quality of reservoir water. Subsequently, the Spanish scientists completed analyses of several reservoirs and have sent their results and data to BOR for verification. BOR scientists also used Landsat and AVHRR data in completing a pilot study to monitor snow-covered areas of the High Atlas Mountains of Morocco. This work, a part of the Moroccan Winter Snowpack Augmentation Project, will be continued for another four winter seasons.

A cooperative project between USGS and Spain to evaluate remote sensing techniques for augmenting conventional mineral exploration methods found that Landsat TM data are particularly useful in the search for tin, tungsten, and uranium deposits in West-Central Spain.

At the request of the Kingdom of Saudi Arabia, USGS prepared and printed color Landsat MSS image maps at 1:500,000 scale for that country's Ministry of Petroleum and Mineral Resources. The USGS 1:250,000-scale Landsat image base maps that were used for the Saudi geologic maps also now serve as the base maps for a new series of soil maps of Saudi Arabia. A geographic map of the Arabian peninsula at 1:2,000,000 scale also has been published and, for its scale, is one of the most accurate and up-to-date maps of the Kingdom. Image maps of the Arabian Peninsula using NOAA-AVHRR data, were prepared, and thermal inertia images of the Peninsula were made, which define previously unrecognized structural features of the Peninsula.

At the request of the U.S Agency for International Development and the Government of Sudan, USGS trained Sudanese scientists to preare Landsat image maps, and printed Landsat MSS color image maps of the drought-stricken Darfur and Kordofan areas.

Department of Agriculture

During 1985, the U.S. Department of Agriculture (USDA) continued to develop and improve remotely sensed data from space platforms for use in research and operational programs.

A significant milestone was reached with the conclusion of the AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing) program on September 30, 1985. The 6-year, multi-agency program was established in 1980 as a cooperative research effort of USDA, the National Aeronautics and Space Administration, the Department of Commerce, and the Department of the Interior. The Agency for International Development acted as an observer, anticipating possible applications of research results in underdeveloped countries.

The goal of the AgRISTARS program was to determine the feasibility of integrating aerospace remote sensing technology into existing or future USDA information systems. From the beginning, research focused on information requirements that were of primary concern to USDA, such as early warning of changing conditions in agriculture, crop production forecasts, land use and productivity, asssessments of renewable resources, conservation practices, and pollution detection. The program was organized into eight project areas and structured around the priority information requirements. A balanced approach was a major factor in the progress made in the areas of research, development, testing, and evaluation. The AgRISTARS program benefited significantly from the unique experience and expertise of the participating agencies.

Each of the projects contributed substantially to advances in practical applications of aerospace remote sensing. For example, research implemented in the Early Warning and Crop Condition Assessment project provided improved methods to detect stress in crops and vegetation, and, in conjunction with meteorological data, to provide timely indications of near-term future crop conditions over foreign production areas.

The Crop Production Forecasting project improved analytical techniques for spectral identification of wheat and was used for identifying corn and soybeans. In this instance, analytical

Interior view of the Remote Sensing Center of USDA's Foreign Agricultural Service where data from the AgRISTARS program are analyzed to assess crop conditions in major agricultural regions of the world.

techniques were made more efficient and less labor intensive than previous visual interpretation methods.

Measuring plant and environmental characteristics played a critical role in crop production forecasting and estimating research. Crop yield models were developed for corn, soybeans, wheat, and barley, as well as a new method for using data from the Advanced Very High Resolution Radiometer instrument on meteorological satellites to estimate the amount of solar radiation on the Earth's surface. Related research in soil moisture emphasized development, testing, and evaluation of techniques to gather soil moisture data remotely and with ground-based instrumentation. Microwave sensing devices were used in many of the soil moisture experiments.

Land-cover inventories, land-use change estimates, and improvement of crop acreage projections were central concerns in the Domestic Crops and Land Cover Research project. Similar research, the Renewal Resources Inventory, included improved methods to collect, display, and use resource information for forest management and planning; to evaluate Landsat technology to support multi-resource inventories and forest planning; and to demonstrate an ability to monitor, classify, and measure disturbances and changes in forest and rangelands.

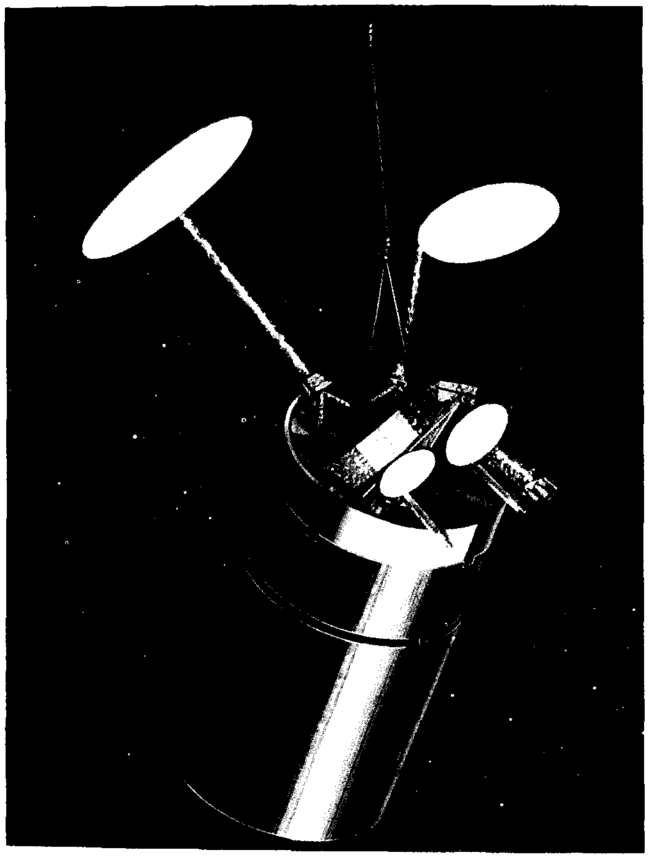
The conservation assessment portion of the Conservation and Pollution project focused on applications in the inventory of conservation practices, use of hydrologic models to estimate water runoff, and efforts to determine the physical characteristics of snow packs. The pollution segment of the project studied conservation practices through use of remote sensing techniques to quantitatively assess sediment runoff, gaseous and particulate air pollutants, and the impact of pollutants on agricultural and forestry resources.

A major test of the feasibility of using remote sensing for the 1987 National Resource Inventory (NRI) proceeded in parallel with the AgRISTARS project during its last two years, and drew upon its research results. The NRI is mandated by the Resource Conservation Act and is to be conducted by USDA's Soil Conservation Service every five years; extensive use of remotely sensed data could markedly reduce expenditures for the inventory. This feasibility test, using Oklahoma, was known as the Remote Sensing Pilot project. In addition to aerial photography of several types, digital data from the Advanced Very High Resolution Radiometer, and Landsat's Multispectral Scanner, and Thematic Mapper instruments were tested. Based on initial results of the tests, it is expected that the next National Resources Inventory will make extensive use of remotely sensed data.

The conclusion of the AgRISTARS program does not signify a diminishing remote sensing research effort in USDA. On the contrary, research will proceed at about the same funding level as under AgRISTARS. USDA's Agricultural Research Service (ARS) will continue investigating the potential for remote sensing as a data source. In 1985, ARS established a Remote Sensing Research Laboratory under a newly formed Agricultural Systems Research Institute to test use of remotely sensed data in all areas of concern to the Department. The Remote Sensing Research Laboratory is located at the Beltsville Agricultural Research Center near Washington, D.C., and is expected to play an important role in developing practical and useful applications.

Federal Communications Commission

During 1985, international and domestic communications networks continued to expand into new services. The International Telecommunications Satellite Organization (INTELSAT) upgraded its global service with launches of the 10th, 11th and 12th satellites of the INTELSAT V series. Those satellites increased to 14 the number of satellites available to INTELSAT's global service. There are 25 domestic communications satellites currently in service, and an additional 20 are authorized by the Commission for construction and launch. The International Maritime Satellite Organization (INMARSAT) has a lease agreement with INTELSAT to provide maritime communications services using the V series INTELSAT satellites in the Pacific and Indian Ocean regions. Satellite communications in the Atlantic Ocean region are provided by two Marecs satellites leased from Aerospatiale and one Marisat satellite in the Pacific Ocean region leased from Comsat General. INMARSAT has executed a contract with British Aerospace to provide three second-generation spacecraft with a service date in 1988. The contract included an option for nine additional satellites. Four new commercial satellite systems have been authorized for international services in the Atlantic Ocean region. Conditional authorizations have been granted to five companies to establish international satellite systems separate from INTELSAT. New technology is developing additional use for satellite delivered communications, such as mobile satellite and radio determination satellite systems. A radio determination satellite is one that allows a subscriber to use a transmitted signal to determine his geographic position.



The next-generation INTELSAT VI communications satellite, nearly 39 feet tall.

Communications Satellites

INTELSAT

At the beginning of 1985, the INTELSAT global communications system consisted of three INTELSAT IVA, and eleven INTELSAT V satellites. During 1985 the operational satellites were reconfigured in operational zones as follows: six V's and one IVA in the Atlantic Ocean Region: three V's in the Indian Ocean; and two IVA's and two V's in the Pacific Ocean Region. Three of the IVA satellites have exceeded estimated maneuver life.

The Commission approved 22 new Earth station facilities to access the INTELSAT system in the Atlantic Ocean Region for INTELSAT (digital) Business System.

Domestic Commercial Communications Satellites

In 1985, the Commission authorized the construction and launch of 20 additional domestic fixed-satellites which will provide communication services through the end of this century. In addition to increasing substantially the available satellite capacity, this action will provide the opportunity for implementation of various innovative techniques and services. Several new entrants to the satellite industry were awarded licenses in this authorization proceeding, including Ford Aerospace Satellite Services Corporation, Martin Marietta Communications Servies Inc., and Federal Express Corporation. To accommodate these new satellites, the Commission relied on its 1983 decision to reduce orbital spacings and assigned locations in the geostationary orbit with 2-degree separations in both the 4/6-GHz and 12/14-GHz bands. Currently, there are 25 launched and operational fixed-satellites with 16 in the 4/6-GHz band, six in the 12/14-GHz band and three operating in both bands. Five satellites launched in the 1970's have been retired and are being replaced by satellites with higher efficiency.

In acting on the 85 applications before it, the Commission established rules for future applications which will ensure that satellites are promptly constructed and launched after authorization. An applicant must have the financial ability to construct and operate a satellite system and demonstrate that its proposals will be promptly implemented to provide services to the public.

The Commission's Advisory Committee on 2° Spacing was established in 1985 to elicit suggestions by industry representatives on the most efficient and economical methods to accommodate satellite operations under reduced spacing conditions. This committee is divided into working groups to consider issues relating to Earth stations, space stations, and coordination. One report, including the report's recommendations, has been adopted by the committee and more reports are anticipated in 1986.

Maritime Satellite Service

National and international efforts to establish a future global maritime distress and safety system are continuing. The International Maritime Organization (IMO) is developing the system which will use terrestrial techniques as well as satellite emergency position indicating radio beacons (satellite EPIRB's) to provide initial distress alerting information from ships to rescue coordination centers. While present plans envisage satellite EPIRB's operating through INMARSAT (geostationary orbit) and COSPAS/SARSAT (polar orbit) satellites, the IMO Maritime Safety Committee will make a final decision on this issue in 1986. The maritime distress and safety system is expected to be fully operational in 1996.

Study Group 8 of the International Radio Consultative Committee has adopted recommended technical characteristics for EPIRB's carried by polar orbiting and geostationary orbiting satellites. A demonstration and evaluation phase of the polar orbiting COSPAS/SARSAT system, with signals transmitted via U.S. GOES satellites, will begin in 1986. Coordinated trials of EPIRB's on satellites of the INMARSAT geostationary system will be carried out during 1986.

Currently, INMARSAT is leasing three operational and three in-orbit spare satellites to serve the Atlantic, Pacific, and Indian Ocean regions. Second-generation satellites, the first of which is expected to become operational in mid-1988, are being built under INMARSAT specifications, and will have a capacity about triple that of the present leased satellites. INMARSAT currently serves about 4,000 vessels through its 44 member-country organization. Thirteen coast stations in ten countries are in operation, with five more expected in 1986.

Aeronautical Satellite Service

The International Conference on the Establishment of an International Maritime Satellite System, London, 1975-1976, adopted Recommendation 4 relating to the use of INMARSAT satellites for multiple purposes, providing both a maritime mobile capability and an aeronautical mobile capability. The International Civil Aviation Organization (ICAO) has approached INMARSAT to investigate the possible use of INMARSAT satellites to satisfy aeronautical requirements. Three satellites of INMARSAT's second generation, the first of which is under construction, will have the capability to operate in a small portion (1 MHz) of the aeronautical mobile-satellite band. The Fourth INMARSAT Assembly of Parties, London, October 1985, amended the INMARSAT Convention to allow INMARSAT to offer services via satellite to the aeronautical community on a competitive, non-obligatory basis. The amendments will take effect 120 days after two-thirds of member countries representing two-thirds of the total INMARSAT investment shares have filed notices of acceptance with the depository. The ICAO Special Council Committee on Future Air Navigation Systems continued to meet in 1985. It is addressing future air navigation systems, including the use of satellites for a coordinated development program in civil aviation.

Direct Broadcast Satellite Service (DBS)

Of eight "first-round" DBS companies granted permits in 1983 to construct Direct Broadcast Satellites, three are progressing in the construction of their authorized satellites. These three permittees will use 200 to 230-watt traveling wave tube amplifiers (TWTA's) in conjunction with various half-CONUS or full-CONUS beam configurations to provide service across the continental United States. Modifications granted in September 1985 will allow two of these companies to increase transponder capability from six channels to eight channels per satellite. Projected completion of satellite construction varies for each company from late 1986 through 1987. These permittees are required to have their satellite systems in operation by the last quarter of 1988.

Additionally, of six "second-round" applicants granted conditional permits in late 1984 and early 1985, one has demonstrated "due diligence" in construction of its satellite system and has been awarded channels, orbital position, and launch authority. In contrast to the three "first-round" companies, this system will use two 16-channel satellites equipped with 100-watt TWTA's to provide DBS service. Advances in antenna and receiver technology were cited in support of selecting mid-power transponders for this system. Commencement of DBS operations for this company is scheduled for mid-1989.

In September 1985, conditional construction permits for new DBS systems were issued to three "third-round" DBS applicants. Upon fulfillment of the "due diligence" requirement, these permittees will be entitled to assignment of specific orbital positions and channels. A "fourth-round" of DBS applications is currently pending.

New Satellite Services

New technology is developing to provide additional uses for satellite delivered communications. Increased capacity in the 12/14-GHz band allows the development of services using much smaller antennas than feasible in the 4/6-GHz band. This has prompted several applications for large private networks of small Earth stations to provide communications services between various business locations. These applications request streamlined licensing procedures which will enable such networks to be constructed more expeditiously and economically.

In addition, on July 12, 1984, in response to a petition from Geostar Corporation, the Commission issued a Notice of Proposed Rulemaking in General Docket No. 85-689, that proposes to implement a radio determination satellite system domestically which would allow subscribers to determine latitude, longitude, and altitude, and to exchange brief coded messages using inexpensive hand-held transceivers. In July, 1985, the Commission allocated frequencies in the 1610 to 1626.5-MHz, 2483.5 to 2500-MHz and 5117 to 5183-MHz bands for radio determination satellite service.

On January 28, 1985, in response to a petition from NASA, the Commission issued a Notice of Proposed Rulemaking in General Docket No. 84-1234, that proposes to allocate spectrum for a mobile satellite service, to establish technical and regulatory guidelines for the service, and to authorize a licensee. The service envisioned by NASA would provide mobile telephone service in rural areas, long-range vehicle dispatch functions, data transmission and data collection, vehicle position determination, message distribution (paging) and emergency communications. Since the release of the Notice of Proposed Rulemaking, the Commission has received voluminous comments concerning the issues raised in the rulemaking. The Commission also received a dozen applications from entities proposing to establish mobile satellite systems. Final comments on these applications were scheduled for evaluation in October.

In the international satellite communications area, the Commission released its policy statement in CC Docket No. 84-1299 establishing the regulatory policies that will be used to consider applications for satellite systems providing international communication services independent of INTELSAT. The Commission found that separate international systems proposed by the Administration will provide substantial benefits to international telecommunications users without causing significant economic harm to INTELSAT. Finding that their applications met its legal, technical, and initial financial qualifications and public interest considerations, the Commission granted conditional authority to establish separate satellite systems to Orion Satellite Corporation, International Satellite, Inc., RCA American Communications, Inc., Pan American Satellite Corporation, and Cygnus Satellite Corporation.

International Conference Activities

The Commission's delegation participated in the Space World Administrative Radio Conference (Space WARC) held in Geneva, Switzerland. The first session was held in August and September, 1985, and the second session will be held in 1988. The objective of the conference is to guarantee all countries equitable access to the geostationary satellite orbit and to the frequency bands allocated to space services. The Commission's Advisory Committee for Space WARC brought several participants into the preparations, including the private sector, which was well represented. After six weeks of difficult negotiations in Geneva, much remains to be done to prepare for the second session. Preparations by the Commission and other federal agencies has already begun, and the rechartered Advisory Committee will be providing private sector participation once again. A number of on-going domestic activities in the radio determination and land mobile satellite areas will have an effect on the U.S. proposals to be developed for that session.

Department of Transportation

Under the Federal Aviation Act of 1958, as amended, the Federal Aviation Administration (FAA)–the aviation component of the Department of Transportation–is responsible for both regulating and fostering civil aviation. It regulates airport safety, promotes aviation security, controls the national airspace to ensure its safe and efficient use, operates a common system of air navigation and air traffic control for the benefit of civil and military aviation, and ensures that civil aviation poses as little risk to the environment as possible. Research, development and engineering programs on aviation safety, air navigation and air traffic control, and the environment are conducted jointly with FAA contractors, and with the National Aeronautics and Space Administration, the Department of Defense, the Department of Commerce, other agencies and organizations.

Under a new federal law and an Executive Order, the Department of Transportation is also responsible for regulating and promoting a commercial expendable launch vehicle industry. The Department's Office of Commercial Space Transportation was established to regulate, license and coordinate responsibilities for the industry, and to promote commercial space transportation in foreign and domestic markets.

Aviation Safety

Fire Safety Research

During 1985, the Federal Aviation Administration (FAA) continued to assess the results of the Controlled Impact Demonstration, in which a remotely controlled Boeing 720 was flown into a prepared impact area. Conducted on December 1, 1984, this demonstration provided data on the effectiveness of antimisting kerosene (AMK), and on the behavior of various aircraft components and equipment under the stress of a survivable accident. The post-crash fire, larger than anticipated, raised questions about the effectiveness of AMK. In the light of that outcome, and of technical issues not yet solved, the Administrator of FAA concluded that the AMK concept is not practical for day-to-day airline operations in the foreseeable future. Therefore, he decided not to issue a Notice of Proposed Rulemaking (NPRM) requiring the use of AMK fuel.

The entire issue of aviation fuel safety research was explored in a 3-day workshop held under FAA sponsorship in October 1985 and attended by over 90 participants, from the United States and foreign governments, including trade associations, fuel companies, airlines, and manufacturers of airframes and engines.

FAA continued to use the rule-making process to enhance fire safety. In March 1985, the agency issued a final rule requiring air carriers to install fire extinguishers and smoke detectors in the galleys and lavatories of their large passenger-carrying aircraft. The smoke detector system will provide a fire warning to the cockpit or passenger-cabin crew. The rule also requires that each lavatory trash receptable be equipped with a fire extinguisher that discharges automatically if a fire occurs in the receptacle. In addition, the rule provides for increasing the number of hand-held fire extinguishers located in the cabins of aircraft capable of seating more than 60 passengers. At least two of these must contain Halon 1211 as the extinguishing agent.

In April 1985, FAA issued an NPRM that will require a more stringent fire test for interior material used in the ceilings, walls, and partitions of aircraft cabins. The use of improved fire resistant material will further delay the onset of "flashover," the point where trapped vapors near the cabin ceiling ignite, spread fire, use oxygen and prevent the possibility of survival. This material also will increase the time for passenger evacuation in the event of an in-flight or post-crash fire.

Finally, in October, FAA issued an NPRM to update several standards in the airport certification regulation (Federal Aviation Regulations Part 139), including those for firefighting equipment and aircraft fueling.

Aviation Security Research

Under Executive direction, FAA accelerated and expanded its efforts to develop improved systems for detecting explosives and weapons concealed on passengers, in baggage, and in cargo. The agency continued to emphasize new approaches to detection, soliciting industry and academia, through more than 120 bid packages that outlined its explosive detection needs. Five proposed new technologies resulting from this solicitation have been funded for a preliminary feasibility study.

Fast neutron inelastic scattering, a new technique for identifying elements of which explosives are composed, continues to show promise. The concept's feasibility was demonstrated in the spring of 1985, and Phase II of the project is proceeding.

One experimental detection system employs thermal neutron activation, a technique in which bombardment by neutrons triggers a reaction that permits identification of the target material. In previous years, this system was tested at Pittsburgh, Boston and Chicago airports, and showed promise of detecting explosives in checked baggage and air cargo. In the spring of 1985, tests using a prototype system were conducted at the Philadelphia airport. More than two thousand pieces of baggage were screened, with an explosive detection probability exceeding target levels, and a false alarm frequency approaching target values. FAA is in the process of streamlining the hardware and software to produce an economically viable system.

Cooperating with several other agencies in recent years, FAA has undertaken extensive research to develop a device that would routinely detect vapors of an explosive carried by an individual. The research centers around efforts to collect, concentrate, and detect explosive vapor from a passenger. Several approaches to the detection of explosive vapor are being pursued under new technology. In particular, FAA has accelerated its work on chemiluminescence, a promising prototype technique.

As a complement to its current bulk and vapor explosive detection projects, FAA is continuing a joint effort with industry to investigate methods to make explosive devices more difficult to conceal.

Airport Pavement Research

FAA is pressing forward its efforts to establish a Pavement Maintenance Management System (PMMS). To this end, FAA maintains its sponsorship of a U.S. Army Corps of Engineers study of PMMS. The system is based on the automation of records and analysis, and will provide managers with timely data that will allow them to select the most appropriate strategies to maintain and rehabilitate pavement.

With the assistance of the U.S. Army Cold Regions Research and Engineering Laboratory, the agency is also pursuing its study of special problems of pavements in cold climates. The objective is to improve pavement resistance to the harmful effects of severe weather conditions.

Through private sector contracts, FAA has funded research to develop materials criteria and improve construction techniques to enhance the durability of pavements. The criteria provide for the effective use of geotextiles to inhibit pavement cracking, thereby reducing maintenance costs. FAA also has provided guidelines for contract fee adjustments based on the quality of materials used in airport pavement construction. This effort will continue and will include all material specifications that have significant influence over the cost of constructing, rehabilitating, and repairing pavements. Research to identify inexpensive additives to strengthen weak soils in place has begun, and is designed to obviate the high transportation costs for importing material.

FAA continued a project initiated in late 1984 to determine the feasibility of developing aircraft arresting systems based on the use of soft ground at the ends of runways. Under study are various materials for use as soft ground, and the length of soft ground that aircraft need for safe deceleration. If the use of soft ground proves workable, FAA plans to issue a standard to assist airports in providing this safety feature.

Airport Visual Aids and Lights

FAA evaluted newly developed runway lighting systems using tritium-powered, self-contained radioluminescent lights. Such systems require no external power source. A preliminary evaluation was conducted of a system that consists of runway edge lighting units, threshold lighting units, an airport identification beacon, and a lighted wind direction indicator. The results showed that the system provided satisfactory visual cues under favorable climatic conditions. Additional testing in adverse weather conditions is in progress. If positive results are obtained, the lighting system would be used for airports in remote areas where power sources are unreliable or non-existent. The system is a potential contributor to air transportation safety in such areas.

The agency also conducted research on a simple and inexpensive way to improve safety at airports, especially during low visibility conditions. The method uses color coding of taxiway centerline lights and taxiway edge lights. The codes identify areas where taxiing aircraft should not stop because of potential interference with aircraft exiting runways, or with the electronic signals of landing systems. The concept is undergoing evaluation at an operational civil airport.

Aviation Weather

During 1985, FAA conducted technical and operational investigations using a Doppler weather-radar support facility at Olive Branch, Mississippi, approximately twelve miles southeast of Memphis International Airport. The Massachusetts Institute of Technology's Lincoln Laboratory carried out operations with the facility, which uses an S-band (Airport Surveillance Radar) ASR-8 transmitter/receiver with Doppler processing capability added by Lincoln Laboratory. The facility's other principal weather measurement-sensors included a 30-unit network of reporting stations, the Memphis Airport's Low Level Wind Shear Alert System, and the University of North Dakota's C-Band Doppler weather radar. The facility also received data from the National Weather Service's WSR-57 radar at Memphis and aircraft tracking data from the Memphis Air Route Traffic Control Center. The University of North Dakota operated instrumented test aircraft in support of the facility.

The primary objectives of the Doppler weather radar program are to:

- resolve the principal uncertainties in algorithms (computer processing procedures) for detecting and displaying en route and terminal hazardous weather
- obtain from system users feedback on the usefulness of proposed data products for improving safety and efficiency
- investigate issues involving the interface between Doppler weather radar and the Central Weather Processor (CWP)
- provide a data base for FAA specifications for interfaces between the terminal Doppler weather radar and the CWP/Next Generation Weather Radar.

During the 1985 operational investigations, the test-bed radar was operated in the following modes:

- as a Doppler weather radar to detect low altitude wind shear at air terminals
- as a network sensor known as NEXRAD, with principal focus on products of particular interest to FAA, such as data on turbulence and layered reflectivity
- for scientific data acquisition characterized by scientist-controlled scan patterns, as in the Joint Airport Weather Studies and Northern Illinois Meteorological Research on Downbursts projects.

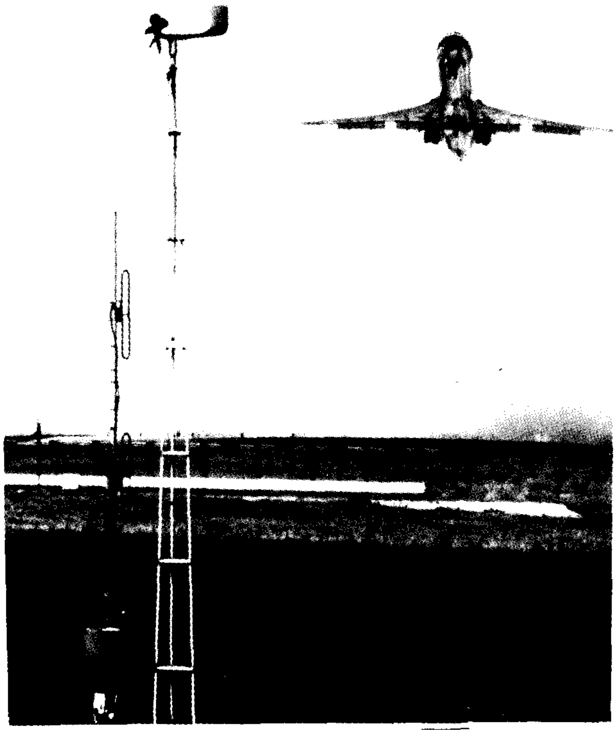
The Memphis-Olive Branch test site operated through the storm season at the end of November, with continued primary interest in developing algorithms and evaluating scanning strategies.

Action on the issue of wind shear training for pilots was encouraged in a report by the National Research Council entitled "Low Altitude Wind Shear and Its Hazard to Aviation." The Council found that "the education and training of most pilots with respect to wind shear and its hazards are inadequate and that the risk posed by wind shear can be reduced very soon by an education campaign directed at all classes of pilots." Spurred by this strong statement, Boeing Aircraft developed a joint proposal with McDonnell-Douglas, Lockheed, United Airlines, and Dr. John McCarthy, a consulting meteorologist. Boeing and its associates proposed to FAA a comprehensive program to develop an authoritative wind shear training aid. The proposed effort will take an industry-wide approach. Its results will be provided to FAA for final distribution as an authoritative basis for implementing individual training programs and syllabi. Procurement action was initiated in 1985.

FAA commissioned the Interim Voice Response System in 1985. This system permits pilots in the continental United States to retrieve weather information by telephone directly from an automated data base. Sixteen systems, using a combination of local and foreign telephone exchange-circuits, are located throughout the country. They provide service to 25 major population centers. Pilots receive surface observations, terminal forecasts, grid winds, transcribed weather broadcasts, convective Significant Meteorological Information, and severe weather forecast alerts. This interim system will help meet the demand for service while the Flight Service Automation System Program is being implemented.

Installation of LLWAS, the Low Level Wind Shear Alert System mentioned previously, continued during 1985. LLWAS provides pilots and controllers with information on wind shear that could cause unsafe landing or departure conditions. The system processes with computer algorithms that compare wind speed and direction from sensors on the airport periphery with wind data for the airport's center. When the system produces an alarm, air traffic controllers provide wind shear advisories to all departing and arriving aircraft. Initially, systems were installed at major airports that experience a high incidence of thunderstorms and the attendant gust fronts. The installation of 21 additional systems during 1985 brings the total number of airports with LLWAS to 80, and a total of 110 airports will be equipped with the system by mid 1986. Concurrently, the

169-254 0 - 86 - 4



The FAA has been developing modifications to the Low Level Wind Shear Alert System (LLWAS) so that it will encompass more localized microburst phenomena. This sensor is off the end of the runway at Atlanta International Airport.

LLWAS at Denver's Stapleton Airport and New Orleans' Moisant Airport were expanded to incorporate additional periphery sensors. Evaluation and testing are continuing at both airports, with the objective of investigating the expanded systems' ability to detect wind shears generated by microbursts.

Another 1985 project involved the establishment of an Aviation Weather Forecasting Task Force comprised of highly qualified individuals from organizations independent of FAA and the National Weather Service. The members are research scientists, research meteorologists, and engineers. Their charter is to study the current system, procedures, and products; identify problem areas; and recommend improvements that could be made in the near term (18 to 36 months) without major capital investments. A final report of this activity is scheduled for release in early 1986.

Air Navigation and Air Traffic Control

National Airspace System Plan

The National Airspace System (NAS) Plan is a technological blueprint first issued in December 1981 and updated on an annual basis. It outlines means for increasing safety, capacity, productivity, and economy in the operation of the Nation's air traffic control and air navigation system through capital investments. The increases will be achieved through higher levels of automation, facility consolidation, and use of new telecommunications technology. FAA continues to implement components of the NAS Plan as described in the subsections that follow.

VORTAC Replacement Program. VORTAC is an acronym for very high frequency omnidirectional range with tactical air navigation equipment. The second-generation VORTAC program has replaced existing units with solid state equipment capable of remote monitoring and control. Wilcox Electronics and International Telephone and Telegraph have provided 950 second-generation navigational aids and have installed 800. The remaining 150 units are being installed by FAA technicians. These new navigational aids are the first FAA systems to have a Remote Maintenance Monitoring (RMM) feature. This innovation enables technicians to perform a ground check in less than five minutes from a remote telephone. With RMM, site visits are required only trimonthly instead of weekly. The reduction in site visits has resulted in increased maintenance productivity.

Airport Surface Detection Equipment (ASDE). ASDE units provide tower controllers with a radar display of the locations of surface traffic for use in controlling the movement of aircraft and other vehicles within the airport area. The new solid-state ASDE-3 equipment will have a greater capability to penetrate heavy precipitation and present a clearer, sharper radar picture under all lighting conditions than did the ASDE-2. Norden Systems of Melville, New York was awarded a $55.6 million contract in 1985 for seventeen ASDE-3 units, with options for thirteen more. Deliveries are scheduled to begin in March 1988.

Microwave Landing System (MLS). MLS is the precision landing system endorsed by the International Civil Aviation Organization as the worldwide standard replacement for the present Instrument Landing System (ILS). MLS overcomes many of the technical and operational limitations inherent in ILS. In many locations it will give air traffic control the ability to eliminate traffic flow conflicts, allowing virtually independent operations at adjacent airports. Unlike ILS, the MLS system will allow multiple precision approach paths. This will provided added flexibility to overcome terrain restrictions and avoid heavily populated areas. The MLS signal is also less sensitive to weather, terrain, and structures around the airport, which makes the system more dependable and easier to site.

The NAS plan calls for installation of 1,250 MLS systems. User evaluation programs were launched

At the FAA Technical Center, a magnetic tape is fed into the new Host Computer System – an important element of the continuing modernization of air traffic control.

with the commissioning of the MLS at Richmond, Virginia, in September 1985. These evaluation programs will assist in avionics certification and will demonstrate to the user community the benefits of MLS. The MLS implementation contract awarded in January 1984 schedules initial implementation for late 1986. The contractor successfully completed the design review in 1985.

Advanced Automation Program. The current Advanced Automation program, initiated in 1982, is central to the modernization of en route and terminal air traffic control (ATC) functions. It is directly related to a number of other NAS Plan programs, and provides increased computer capacity to perform new ATC functions that will be required during the 1990's and beyond. The program is composed of two major elements, the Host Computer System and the Advanced Automation System (AAS). After a design competition between International Business Machines (IBM) and Sperry, an acquisition contract for the Host Computer System was awarded to IBM on July 26, 1985. The contract involves replacement of the present IMB 9020 computers in twenty Air Route Traffic Control Centers (ARTCC's) and their support facilities. The first system commissioning at an ARTCC is scheduled for November 1986, and the last for December 1987. Meanwhile, AAS development is proceeding under two competitive design contracts, totaling nearly $247 million, awarded to IBM and Hughes Aircraft in August 1984. FAA is expected to select a winning AAS design and award an acquisition contract in January 1988.

Aeromedical Research

Improving Pilot Judgment and Decision Making

Aviation statistics indicate that 52 percent of fatal accidents and 35 percent of non-fatal accidents involve judgment errors by pilots. FAA research suggests that a possible explanation for this is that traditional aviation training and certification programs stress the acquisition of knowledge and skill development, while regarding judgment solely as a by-product of experience. The FAA Office of Aviation Medicine is directing an international industry/government program to evaluate materials for systematically developing judgment as part of the flight training process. These materials include training manuals and low-cost audiovisual aids that explain the risks associated with various flying activities, the underlying behavioral causes of typical accidents, and the effects of stress on pilots' decision making. The assumption is that pilots receiving such training would develop positive attitudes toward safety and avoid unnecessary risks.

Joint testing by FAA and the Canadian Air Transportation Administration in a series of five independent studies indicated that pilots receiving the prototype judgment training materials outperformed their contemporaries during inflight tests. The differences were statistically significant and ranged from approximately 10 to 40 percent fewer judgment errors. In the largest and most recent evaluation of the prototype materials, conducted at 10 flight schools in the United States, 80 percent of the students and 77 percent of the instructors participating recommended that the program be adopted. Primarily as a result of these evaluations, other nations such as France and Australia have begun evaluation programs. In addition, the U.S. Air Force has integrated the FAA-developed materials into one of its training programs for transport-pilot instructors.

Office of Commercial Space Transportation

Executive Order 12465, issued February 1984, and the Commercial Space Launch Act of 1984 designated the Department of Transportation as the lead agency within the federal government to encourage, facilitate, and promote a commercial expendable launch vehicle industry. The Executive Order and the Act also vested the Department with regulatory, licensing, and coordinating responsibilities for this new industry.

The Department's management and oversight responsibilities are separated into two broad categories, regulation and promotion. By law, the Department's mission is to regulate commercial space transportation activities. The Department also has responsibility to promote commercial space transportation in foreign and domestic markets. In 1985, the Office of Commercial Space Transportation reviewed government policies affecting the commercial space industry. This was an important first step in fashioning a regulatory framework specifically tailored to govern commercial launch companies carrying payloads to orbit. The Office also established an interagency working group of representatives from the Department of State, Defense, and Commerce, the National Aeronautics and Space Administration, and the Federal Communications Commission to identify regulatory issues implicit in a commercial space transportation initiative and to determine appropriate methods for resolving them. This Commercial Space Transportation Interagency Committee works with the Department to coordinate and expedite the Government's review of launch proposals, license applications, and regulatory issuances.

Members of the Secretary's Commercial Space Transportation Advisory Committee established in 1984, represent a broad range of companies having interest in commercial space transportation. It includes both small and large launch firms; representatives of satellite, finance, and insurance communities; and other organizations with an interest in private-sector space transportation. The Committee met twice in 1985 to discuss issues of promotion and facilitation, much like the Interagency Committee advises the Department on matters of regulation. Among the issues on the Committee's 1985 agenda were financing and insurance for commercial space ventures, licensing procedures for commercial launch activities, use of national launch ranges, and maintaining the confidentiality of launch firms' proprietary data.

Regulatory Activities

In February, the Department published for public comment its first major policy statement, which outlined the history and rationale that support the forthcoming launch regulations, as well as the actual licensing policy. This policy statement provided the first official, although preliminary, guidelines for the procedures and conditions that commercial ELV operators would have to meet in order to secure a launch license. The policy statement, along with the public comments it generated after publication in the *Federal Register*, will culminated in a draft regulation to be issued in February 1986. The draft regulation, pending promulgation of final regulations, will provide official guidance for the new industry.

Also in February, the Office of Commercial Space Transportation issued the first mission approval for a commercial launch activity [Space Services, Inc. (SSI) of Houston, Texas]. SSI is a new entrepreneurial firm of exactly the type that the Act seeks to encourage. Previously, under the review process dictated by the International Traffic in Arms Regulations (ITAR), federal approval of license applications had required around six months of reviews, approvals, and agency coordination. The Office of Commercial Space Transportation is now able to deliver a decision on launch activity in less than six weeks.

The Department is also responsible for ensuring that commercial space launch operators have insurance coverage adequate to protect against liability claims by third parties–persons not involved in space activities. To implement this authority, the Office of Commercial Space Transportation issued in May of 1985 an Advanced Notice of Proposed Rulemaking concerning third party liability insurance requirements. In addition to protecting against liability under U.S. international obligations, the insurance will cover the federal government's liability to U.S. nationals incurred as a result of the launch activities. Such liability could arise under the Federal Tort Claims Act where the United States is involved in a commercial launch by a private concern from a range belonging to the federal government.

The Administration's decision to promote a commercial space transportation industry also encourages launch firms to use the facilities and services available at national launch ranges. This has placed the Office of Commercial Space Transportation in a brokering role, helping to arrange agreements between launch firms and NASA or the Air Force, the two owner-operators of the Nation's ranges. This year, under the Office's sponsorship, SSI negotiated a contract to conduct a series of commercial launches from NASA's Wallops Island launch facility.

The Office also established a communications network with the Air Force to reduce some of the red tape normally associated with interagency coordination of agreements and approvals. As a result, changes were made in the policies and procedures that prevail at national ranges. These changes, like the newly established channels of communication, will benefit the commercial space transportation constituency.

Promotional Activities

Since a predictable, supportive government policy is crucial to the development of any new industry, the Office of Commercial Space Transportation, in its advocacy role for the new industry, took part in numerous interagency deliberations. The Office also participated extensively in several high-level working groups involved in developing space policy. As a result of this participation, the Office produced the following:

- a forecast of the market in which commercial expendable launch vehicles will compete, with the target market set for 1989 through 1994
- an analysis of Shuttle operations and pricing
- an analysis of the price, time, and reliability factors that affect customers' choice of launch vehicles
- an interagency analysis of the effect high launch prices have on the competitive viability of space-based industries such as telecommunications satellites, upper stages and materials processing
- an analysis of risk to the nation's launch capability in the event of insufficient Shuttle capacity or an unexpected surge in demand, and
- a report on international competitiveness in launch services, developed for the National Security Council while participating in an OMB working group.

The Office also served as the Government's spokesman for expendable launch vehicle operators during the development of national space policy priorities. When Transpace Carriers, Inc. (TCI) filed a petition with the U.S. Trade Representative against the European Space Agency's (ESA) Ariane launch vehicle, DOT representatives participated in the investigations and consultations that followed. In this instance, TCI charged ESA with predatory pricing practices, against which neither TCI nor any American launch firm could compete, in violation of Section 301 of the Trade Act of 1974. Recognizing that ESA's practices were not unreasonable in light of U.S. practices, on July 9, 1985, the U.S. Trade Representative recommended that the President deny the petition filed by TCI.

In sum, 1985 set the stage for a new domestic industrial initiative in the form of a space-based freight service. As with many new private-sector initiatives, especially those in transportation, a regulatory policy is called for that is designed and administered with a light touch that will encourge expansion. Uniform, government-wide policy that is directed toward the same goal is also required. The Office of Commercial Space Transportation is taking a leading role in this effort, initiating a series of steps that will result in a domestic industry capable of competing in an international market.

Environmental Protection Agency

The Environmental Protection Agency (EPA) cooperated with NASA in developing and applying a number of aerospace technologies, including the use of a geographic information system for monitoring the environment and factors that affect it; Landsat estuarine assessments; the use of remote sensing data in an impact analysis of alpine ecosystems; mathematical models for acid deposition studies; the use of high-altitude photography in support of provisions of the Resource Conservation and Recovery Act (RCRA) relating to waste-site location, permit writing, site analysis, enforcement activities, and the underground storage tank program. Aerial photography is also used to support waste-site investigations conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as Superfund.

Monitoring and Assessing the Environment

Geographic Information Systems

Geographic Information Systems (GIS) provide a means for computerized manipulation of multiple data sets from or related to Landsat satellites, photography, topography, land use, vegetation, soils, weather, population distribution, geology, and sampling locations for monitoring and assessing the envionment. The locations of spatially variable information are organized and referenced using cartesian (x,y) coordinates and grid cells. The information is then retrieved by subject (such as land use, soil type, and water well location) and manipulated, combined, and displayed as complex geographic data bases. Processing and manipulating the GIS data base through various computer operations result in a series of thematic overlays describing many environmental variables that relate to a particular site or region. Applications for the overlays include hazardous waste permit analysis, local and regional environmental impact assessment, monitoring systems design, and compliance monitoring.

Landsat Estuarine Water Quality Assessment of Silviculture and Dredging Activities

The objective of this project was to define and demonstrate the role of Landsat multispectral scanner data in monitoring environmental impacts in estuaries and their associated drainage basins. Landsat created an invaluable and almost irreplaceable data base for investigations correlating land-use and water quality.

The data were examined to determine whether they could be used in detecting and delineating temporal distributions of water color and land-use categories in a bay system. Water color distributions were easily distinguished and the distribution of such water types as acidic swamp and forest runoff and turbid river and clear gulf water were monitored under numerous environmental conditions. Land-use categories also were detected and delineated with an emphasis on silviculture (forestry) such as clear-cutting, pine plantations, and swamp and forest communities. In addition, Landsat data were successfully used to monitor the effects of both natural and man-made structures – holes in barrier islands, channels, oyster bars, and bridges – on the hydrodynamics of the bay.

The Landsat-derived land-use activities followed trends in the improvement or recovery of water quality. The use of Landsat data proved to be a more accurate method than traditional water sampling schemes for monitoring water distributions and associated water patterns. However, the collection of tandem surface-truth data would have greatly improved the quantitative aspects of this project. Moreover, if water quality samples concurrent with Landsat overpasses were required, the most accurate presentation of water patterns would result, since these water quality data could be used as calibration points during the classification stages of Landsat imagery analysis.

EPA/NASA Elk Mountain Remote Sensing Technology Demonstration

Throughout the Intermountain Physiographic Region there are various activities, such as hard-rock mining, that pose an immediate threat to alpine and subalpine environments. These environments are representative of unique ecosystems that contain sources of domestic water supplies, contribute to surface hydrology, and act as a support base for various types of recreation.

EPA and NASA are cooperating to develop a geographically based information and inventory system as a first step to ensure protection of headwater environments. The two main objectives are to compare two types of remote sensing platforms relative to their capabilities and limitations for use in environmental assessments and to inventory selected areas in the Elk Mountains of Colorado. The two types of platforms to be evaluated are support aircraft from EPA's Environmental Monitoring Systems Laboratory in Las Vegas and satellites; and the sensing methods to be used are multispectral scanning and photography. The capability of the two types of platforms to accomplish the objectives are being evaluated individually and jointly as part of an integrated assessment and inventory strategy.

Acid Deposition Studies

NASA is helping EPA develop methods to model acid deposition from the Philadelphia metropolitan area. This area can be visualized as an 80- to 100-kilometer square containing a large number of individual sources of pollutants such as sulfur dioxide, hydrocarbons, and the oxides of nitrogen. This modeling study seeks to characterize how the pollutants affect the chemical composition of rainfall reaching the ground in the first few hundred kilometers downwind of the sources. It will compare results of calculations using mathematical models of meteorological and chemical processes with the results of field observations.

The mathematical models are of two types. First is a meteorological model called the Mesoscale Atmospheric Simulation Model (MASS) developed for Langley Research Center. This model was tested by the Goddard Space Flight Center and provided an excellent simulation of the weather. The second model, the Sulfur Transport Eulerian Model (STEM), was developed jointly by the Universities of Iowa and Kentucky with financial support from NASA and EPA. Both models run on Langley's computers and represent the state of the art in their respective disciplines.

Since the study's inception in March 1985, several tasks have been accomplished. First, meteorological conditions for three experimental periods have been simulated successfully. The simulations are necessary, since the atmosphere at levels above the surface currently is observed only at 12 hour intervals, and at stations approximately 400 kilometers apart. Calculations of meteorological conditions with the models yield resolutions that are more detailed than those obtained from observations alone.

Once the meteorological fields have been calculated, STEM performs the functions of modeling the chemical transformations occurring in the atmosphere, the transporting of the various chemical species, and the removal of the species by rain. Both STEM and MASS will be used to simulate field experiments and to analyze major processes contributing to acid deposition on a mesoscale basis. The field results from the EPA experiments indicate that nitrate deposition resulting from urban-industrial sources can be very significant. The models will be used to determine the origin of nitrates by varying contributions from several sources such as automotive emissions and petrochemical processing emissions and then comparing calculated results. In this way, the models and field efforts are mutually supportive.

High-Altitude Photography

The Resource Conservation and Recovery Act requires states to inventory open dumps and landfills associated with municipal and industrial activities. Similar inventories of surface impoundments are required under the Clean Water Act. These inventories help states determine and control the potential impact of seepage, drainage, and plumes from surface impoundments, landfills and open dumps.

In support of state efforts, scientists from EPA acquire and analyze aerial photographs, obtained by NASA U-2 flights, to help locate and inventory hazardous waste sites. Aerial photography provides an accurate and cost-effective way to supplement other sources of information such as industrial directories, government records, thematic and topographic maps, and letter surveys that may provide only partial information, or may be out-of-date. The aerial photographic inventories serve as a basic guide to sites and provide general identification and descriptions.

In one application, specialists were able to acquire high-altitude aerial photographs covering the State of Pennsylvania, about 48,000 square miles, in 8 hours of flight time. The photographs located approximately 3,500 landfills and dumps and several times as many impoundments in the state. Similarly, Gulf Coast areas of Mississippi, Alabama, and Florida, about 21,000 square miles, were photographed from high altitude with a conventional mapping camera in less than 9 hours of flight time. These photographs allowed identification of over 600 waste sites. Sites are classified according to the kind of facility or activity associated with them, such as industrial, municipal, agricultural, mining, oil or gas, sewage treatment, and land disposal.

Aerial Photographic Septic Tank Assessments

The Clean Water Act authorizes the funding of sewage collection and treatment facilities. When implementing this legislation in areas serviced by septic systems, EPA has recognized the need to document the condition of these systems. Unfortunately, available field survey methods have technical limitations, and public records are usually incomplete. Therefore, researchers at EPA have developed aerial photographic techniques to help identify failures in septic systems.

An area under study is photographed using both color infrared and standard color photography at a scale of 1:8,000. This scale provides the necessary resolution, while allowing enough area coverage to make the method cost-effective. The color infrared imagery is the primary source for interpretation because of its ability to detect subtle changes in vegetative growth patterns. The standard color photography is used primarily for comparative purposes.

The analyst uses high-powered optics and stereoscope to examine each lot in the study area for signs of unusual vegetative growth, plant foliage stress, and excessive soil moisture levels. Growth-stress-death vegetative patterns associated with upward or lateral movements of septic system effluent appear different from the surrounding vegetation on both standard color and color infrared photography.

Analysts can also identify secondary indications of septic system failures. Indicators of such failures may be: small ditches or trenches constructed by home owners to remove the effluent from failing systems, small hoses or pipes to reroute wash water from an overloaded system, and coverings of an impervious material, such as clay.

Aerial Photography for RCRA/CERCLA

Remote sensing projects support the process of issuing permits for facilities, site analysis, enforcement activities under provisions of the Resource Conservation and Recovery Act (RCRA); and site operations monitoring, topographic and flood mapping, demographic change analysis, and the Underground Storage Tank program. Aerial photography is also the most commonly used remote sensing technique for supporting waste-site investigations conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), often called Superfund. The principal aerial photographic system used is the 9″ × 9″ mapping camera.

Color and color infrared files are most frequently used, since these media provide enhanced differentiation of subtle spectral characteristics associated with such features as surface leachate, surface water turbidity, soil moisture, and vegetation stress. Various types of aircraft are used at different flight altitudes. Archival aerial photography provides a valuable source of information for the historical analysis of hazardous waste sites and is routinely used. Moreover, image analysts who interpret aerial imagery are fully qualified to provide expert witness testimony on the analysis findings.

EPA conducts four basic types of remote sensing under RCRA or CERCLA. First, priority is given to emergency response projects under hazardous material release situations requiring rapid assessment of conditions at a site. When current information on a site is required, the practice is usually to acquire new photography. Data analysis may be conducted on this new imagery or on historical imagery taken during a particularly significant period in the history of the site. Second, intensive site-analysis projects are performed on selected sites to document changing conditions over a period of time. Third, waste-site inventories are conducted over large areas to establish a base-line reference of sites. In addition, a number of special purpose products are produced using more advanced technologies to process photographic data. Fourth, photogrammetry is employed to produce detailed topographic maps of waste-sites. As an expansion of the applications of photogrammetry, flood-plain maps defining the 1 in 25, 1 in 50, and 1 in 100-year flood plain are developed for hazardous waste-sites. This effort involves combining topographic data derived from photogrammetry with hydraulic or stream-flow data sets.

National Science Foundation

The National Science Foundation (NSF) continues to support basic research in the astronomical and atmospheric sciences. NSF is lead agency for federal support of ground-based astronomy, and in 1985 contributed almost 70 percent of the federal funding for this type of research and 50 percent of the federal support for academic and theoretical research in astronomy. Funding is made available through five astronomy grant programs serving more than 140 universities and three National Astronomy Centers.

In the atmospheric sciences, NSF provides the primary backing for research by universities and both nonprofit and profit-making organizations in the United States. It also supports the National Center for Atmospheric Research (NCAR) and the Upper Atmospheric Facilities (UAF) program. NCAR, located in Boulder, Colorado, coordinates and conducts large scientific research programs that would be beyond the scope of a single university. The UAF supports four incoherent-scatter radar facilities in a chain stretching from Greenland through the United States and Puerto Rico to Peru.

Astronomical Sciences

In 1985, one of the most exciting events was the initiation of construction of the Very Long Baseline Array (VLBA), a set of ten 25-meter radio antennas located across the United States from Hawaii to the Caribbean. The VLBA will be operated as a single instrument providing extremely fine detail in maps of energetic cosmic sources such as the centers of galaxies and regions where stars are forming.

Scientific progress has been made in visualizing the structure of large jets from the center of a radio galaxy and of the expanding envelope left from the explosion of a star. These high quality images were made possible by using a supercomputer to process data from the Very Large Array, located near Socorro, New Mexico.

An area of growing interest is the study of the Sun's oscillations. Different parts of the Sun vibrate with different velocities. Intensive measurement and analyses of the velocity patterns on the Sun's surface can unfold the temperature, pressure, composition, and other features below the visible surface of the Sun.

Atmospheric Sciences

Atmospheric sciences range from studies of the surface of the Sun to climate information recovered from analyses of ocean cores. In 1985, atmospheric scientists emphasized the following activities:

- continued studies of atmospheric chemistry and mesoscale phenomena (those 10 to 100 kilometers in spatial extent)
- ocean and atmosphere coupling, especially those conditions in the Pacific Ocean that influence U.S. climate
- continued development of a prototype computing system to give universities capabilities to access interactively and analyze graphically atmospheric and oceanic data. This system will provide real-time and archived satellite and ground-based data for research and educational purposes
- use of supercomputers for numerical simulation of space plasma phenomena that are responsible for solar-terrestrial interactions.

In addition, the National Center for Atmospheric Research is in the process of establishing high speed satellite communications between its computer facilities and several universities. The hardware and software involved are being considered as one element of an NSF network linking supercomputer centers.

Smithsonian Institution

The Smithsonian Institution contributes to national space goals through a broad program of basic research at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts, and through the public exhibits, lectures, and education programs of the National Air and Space Museum (NASM) in Washington, D.C. NASM also pursues basic research in planetary geology and terrestrial remote sensing through its Center for Earth and Planetary Studies.

Space Sciences

High-Energy Astrophysics

Research in 1985 included continued reduction and analysis of high-quality, high-sensitivity, x-ray data from the High Energy Astronomy Observatory satellites HEAO-1 and HEAO-2 (Einstein). For example, the Einstein Medium Sensitivity Survey was extended to include more than 500 x-ray sources. When completed, this survey will identify and catalog representative samples of quasars, active galaxies, and stellar coronal sources. It will also provide important information on the x-ray properties of clusters and groups of galaxies.

Using Einstein data, SAO scientists have shown that x-ray emission is a universal property of quasars. In addition, analysis of x-ray emission from 55 elliptical-like galaxies has shown that a hot, gaseous envelope, or corona, may be a common feature of all such bright objects. This lends further evidence to the theory that some of the so-called missing matter of the universe may be in great dark halos surrounding galaxies. The data also offer an ideal means for investigating forces of gravity in regions extending far beyond the visible luminous material seen in conventional optical images of such galaxies.

Infrared Astronomy

A small, helium-cooled, infrared telescope was flown as part of the Spacelab 2 package aboard the Space Shuttle launched July 29. During the week-long flight, the telescope mapped diffuse infrared emissions from celestial sources in wavelengths not previously observed, measured the Shuttle-induced contamination of the observing environment, and tested the properties and behavior of large volumes of superfluid helium in space.

Gravity Research

In preparation for the proposed deployment of a tethered satellite from the Space Shuttle, an SAO group investigated possible applications of using such a system, as well as any related operational hazards.

Planetary Sciences

Lunar Sample Studies

A reinterpretation of the geologic history of the highlands crust underlying the Apollo 16 lunar landing site is emerging from the studies of a consortium organized by SAO. The consortium has been studying the petrology, trace-element chemistry, gas-retention ages, and magnetic imprints of a breccia collected from the rim of the North Ray Center on the lunar surface during the Apollo 16 mission.

A comparison of the Carbon 14 (radiocarbon) content of lunar samples and Antarctic meteorites is being conducted in an attempt to determine the Carbon 14 abundance in the solar wind and the terrestrial age of the recovered meteorites.

Comparative Planetology

Planetary work at NASM's Center for Earth and Planetary Studies in 1985 focused on two features of Mars: the boundary between that planet's terrain and smooth plains, and the tectonic evolution of the Tharsis Plateau. The Tharsis ridge system was analyzed with respect to orientation, extent, and relative age of formation. In other investigations, field studies of the Columbia Plateau in the northwestern United States resulted in development of a fold model for explaining the evolution of both the Columbia and Tharsis ridges. Also, the Center continued work in cooperation with SAO on the geologic map of Jupiter's satellite Ganymede.

169-254 0 - 86 - 5

Terrestrial Research

The Center's terrestrial research program used orbital remote sensing data to concentrate on investigations of arid environments. For example, field work and analysis of satellite data were combined to develop a working model of the morphology and desert formation processes in the Upper Inland Niger Delta, Mali. The Center also explored the use of thermal infrared satellite data for discriminating rock units in arid, volcanic, and sedimentary terrains.

Department of State

Since its earliest years, the U.S. civil space program has emphasized an active program of international cooperation. The Department of State strongly supports this international effort, from which the United States benefits significantly.

During 1985, the United States initiated discussions with several nations concerning participation in the largest international cooperative space project in history: the permanently manned Space Station. The Department of State worked closely with NASA and other interested agencies to ensure that this project would advance the Nation's foreign policy interests. In the spring of 1985, NASA signed Memoranda of Understanding with the European Space Agency, the Science and Technology Agency of Japan, and the Canadian Ministry of State for Science and Technology concerning the design phases of the Space Station. Since that time, the Department of State has become the lead agency in government-to-government talks on the Space Station, hosting the first round of talks with European nations in November 1985. This effort is expected to lead to formal negotiations in 1986 on construction and operation of the Station. The Department of State believes that the Space Station project offers a major opportunity to demonstrate U.S. leadership in science and technology, and to establish a positive new model for large-scale technological cooperation.

The Department of State participated actively in interagency discussions of major space policy issues, including the pricing of Space Shuttle launch services and the transfer of U.S. land remote sensing systems to the private sector. The Department continued its efforts to ensure the most favorable international environment for U.S. activities in space, including the commercial use of space. The Department also assisted NASA and other agencies on operational matters, such as the negotiation of Space Shuttle emergency landing rights on the territories of other nations.

As in the past, the Department of State played a leading role in U.S. participation in international bodies concerned with space issues. Within the United Nations (UN) system, the most important of these bodies is the Committee on the Peaceful Uses of Outer Space (COPUOS).

Activities Within the United Nations

The Outer Space Committee

The COPUOS has been foremost among the multilateral institutions concerned with outer space issues. It was established by the UN General Assembly in 1958 based on a proposal presented by the United States and 19 other nations for the purpose of promoting international cooperation in the peaceful uses of outer space, and its historic role has been very significant. In its first twenty years of existence it maintained an outstanding record as a forum for exchanging scientific information. It produced five international conventions on space, of which four are widely accepted and constitute the fundamental body of space law. These four conventions were the product of sound scholarly, technical, and legal analysis. For many years COPUOS has dealt with questions involving remote sensing. It has also considered questions relative to the use and regulation of nuclear power sources in space vehicles, the use of geostationary orbit, and the definition and delimitation of air space and outer space. However, in recent years there has been a serious deterioration of COPUOS' scientific and technical focus, in part spawned by efforts to involve it in disarmament and other matters beyond its purpose and competence. The Soviet Union and its allies have attempted – so far without success – to give COPUOS a role on questions about the militarization of space, which are now considered in other multilateral forums, and have exploited COPUOS debates to press the issue, notwithstanding its absence from the formal agenda. These attempts have adversely influenced the atmosphere in which business is conducted, and have made dispassionate consideration of the scientific and legal issues on COPUOS' agenda more difficult to achieve. The introduction of such divisive issues has, moreover, placed the consensus principle – on which COPUOS' past successes have been based – under unprecedented strain. From the standpoint of the Department of State, COPUOS' deterioration has been especially troublesome at this time when the United States envisions a substantial expansion in its scientific and commercial space activities, including those related to launch vehicles and remote sensing satellites.

The United States wishes to re-establish COPUOS' effectiveness and has worked closely with its allies toward that end. At a meeting of COPUOS in June 1985, the United States and seven other Western states–Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, Turkey, and the United Kingdom–jointly sponsored comprehensive proposals designed to strengthen COPUOS' science and technology activities and to improve its working methods. So far, the results have not been promising; although the atmosphere during COPUOS' 1985 sessions was an improvement on that of the previous years, many member states remain indifferent to the need for serious change.

UN General Assembly (UNGA)

Each year, UNGA's Special Political Committee reviews the issue of international cooperation in the peaceful uses of outer space and adopts a resolution to guide the work of the Outer Space Committee and its subcommittees for the following year. In the 40th session of the General Assembly, the Soviet Union insisted upon support for its disarmament rhetoric, and particularly its anti-Strategic Defense Initiative campaign, by advancing proposals for a new world space organization and a new UN conference on space. The Soviets claimed the proposals would result in comprehensive assistance to developing countries under the so-called condition of non-militarization of outer space. The United States and its Western allies rejected this argument, noting that the concept of non-militarization was advanced for propaganda purposes; that the Western industrialized countries provided 92 percent of all UN development activities, while the Soviet Union and its allies provided less than one percent; and that there should be no pre-conditions to international cooperation in space. Ultimately, the Soviet Union withdrew its insistence on UNGA recognition for its proposals when no support was forthcoming from developing countries. A consensus resolution was negotiated and adopted providing for no major changes in the agendas of the Outer Space Committee and its subcommittees during 1986.

Communications Satellites

In June 1985, the Department of State established a Bureau of International Communications and Information Policy. It was created in recognition of the importance, for U.S. national interests, of rapid technological developments in computers, communications, and information systems.

International Telecommunication Union (ITU)

The first of two sessions of ITU's World Administrative Radio Conference on the Planning of the Geostationary Satellite Orbit and the Space Services Utilizing It (Space WARC) was conducted August 8 to September 16, 1985, to review the situation which now exists with regard to orbital use, and to address criteria and principles which will be used by the second session to plan or otherwise structure a procedural approach for allocating access to the geostationary orbit and associated frequency spectrum. The conference was convened in response to developing countries' concerns that the current regulatory process might allow current users of the geostationary orbit to monopolize the resource. Many of the developing countries wished to assign portions of the orbit and spectrum to every country regardless of any intent or ability to use those resources, thus creating artificial scarcities. After difficult negotiations, a compromise was reached which, if maintained by the second session, protects the interests of the United States. It improves on the flexible regulatory procedures governing the portions of the spectrum currently used by most communications satellites, while accommodating the concerns of developing nations by establishing a planning procedure for several portions of the spectrum to guarantee the future access of all countries.

During 1985, the United States also agreed to participate in the newly established Center for Telecommunications Development for the purpose of providing pre-investment assistance to developing countries in establishing telecommunications infrastructure projects. U.S. support of the Center's activities will be provided by industry.

International Communications Satellite Organization (INTELSAT)

In 1985, the United States reached a decision to authorize the establishment of international satellite communications systems separate from INTELSAT for business, video, and other private purposes. In October 1985, the tenth Assembly of Parties ratified a decision by the INTELSAT board to approve, in principle, the provision of planned domestic services by INTELSAT.

International Maritime Satellite Organization (INMARSAT)

At the fourth session of the INMARSAT assembly held in London, October 14-16, 1985, amendments to the INMARSAT convention were adopted, as well as an operating agreement allowing INMARSAT to provide aeronautical communications services. The assembly also adopted an international agreement on the use of INMARSAT ship-Earth stations within territorial seas and ports.

Arms Control and Disarmament Agency

The United States Arms Control and Disarmament Agency (ACDA) devotes considerable attention to the subject of arms control in outer space. As an agency of the Executive Branch concerned primarily with the potential for arms control to enhance U.S. national security, ACDA plays a key role in the development and support of U.S. arms control policy. With increased emphasis on the potential use of space over the last few years, this role has grown in importance.

In proclaiming National Space Policy on July 4, 1982, the President stated:

> The United States will continue to study space arms control options. The United States will consider verifiable and equitable arms control measures that would ban or otherwise limit testing and deployment of specific weapon systems, should those measures be compatible with United States national security.

On March 31, 1984, in a Report to the Congress on U.S. Policy on Anti-Satellite (ASAT) Arms Control, the President reaffirmed that policy. It remains in force today.

U.S. Space Arms Control Activities

During 1985, ACDA was heavily involved in preparing for the Nuclear and Space Talks, a new series of bilateral arms control negotiations with the Soviet Union. The Nuclear and Space Talks are composed of three separate negotiating groups, one of which addresses defense and space issues. In this forum, the United States is proposing to the Soviets that both sides explore further the possibility of a cooperative transition to greater reliance on defensive systems. The United States is also proposing that the sides join together in an "open laboratories" initiative with respect to strategic defense research. Under such an initiative, regular and reciprocal briefings on each other's strategic defense research programs would be conducted, and opportunities would be provided for visits to associated research facilities and laboratories. The United States views this initiative as an example of the type of joint effort which will ensure a stable transition to greater reliance on defenses. At the same time, the United States has made it clear to the Soviets that the United States is committed to pursuing its strategic defense research program, that its program is permitted by the ABM Treaty, and that it will conduct the program in full compliance with the Treaty and all other international obligations.

International Discussions on Space Arms Control

ACDA continues to pursue U.S. space policy objectives in two multilateral forums each year: the United Nations General Assembly (First Committee) and the Conference on Disarmament (CD) in Geneva. For several years, the basic issue in both bodies has been whether the United States will agree to a resolution or committee mandate calling for multilateral negotiations of a treaty or treaties limiting or banning certain activities in outer space. In March 1985, the CD established a committee to examine issues relevant to the prevention of an arms race in outer space. The position of the United States remains that, while all aspects of arms control in outer space should be studied, there has been insufficient analysis of the need for, and verifiability of, a major new agreement for the control of weapons in outer space to justify multilateral negotiations. However, the U.S. does support the formation of a specialized ad hoc committee in the CD with a non-negotiating mandate to address space arms control issues, including a review of the current legal regime with regard to space and discussion of existing and future proposals.

Space Policy

ACDA is deeply involved in the formulation of U.S. space policy. ACDA co-chairs the Interagency Group on Defense and Space, which addresses space arms control issues, and participates in the interagency group that defines U.S. policy regarding the Strategic Defense Initiative (SDI) research program. As progress is made in determining the technical feasibility of eliminating the threat posed by strategic ballistic missiles, ACDA will play a leading role in examining the arms control implications of the SDI. ACDA also provides members, advisors, and legal experts for the bilateral and multilateral negotiations.

In addition, the agency participates in the work of the Senior Interagency Group on Space which considers a broad variety of space issues such as development of the planned U.S. Space Station. Another interagency group in which ACDA participates is tasked with reviewing the arms control implications of bilateral governmental space activities and sales of space-related items.

The United States remains committed to seeking effective and verifiable arms control options. In his remarks to the 40th Session of the United Nations General Assembly on October 24, 1985, President Reagan again called for "radical, equitable, verifiable reductions in these vast arsenals of offensive nuclear weapons." He went on to note that "the ballistic missile is the most awesome, threatening, and destructive weapon in the history of man. . . . Ultimately, we must remove this menace – once and for all – from the face of the Earth." Reducing the potential for the use of space as a conduit to inflict nuclear destruction on another nation remains a high priority.

United States Information Agency

An important activity at the United States Information Agency (USIA) is to inform the world about American space programs and the benefits that they can bring to all mankind. All forms of communications, including direct satellite television broadcasts, live radio interviews, newspaper stories and features, exhibits, videotape showings, and overseas visits by astronauts and scientists, have been used in this effort. Space Shuttle flights receive particular attention, with emphasis placed upon international participation in these missions as well as their commercial usefulness. The spotlight has also focused on plans to build, within a decade, a permanently manned space station. Friends and allies of the United States have been invited to participate in planning, developing, operating and using the Station.

Voice of America

The Voice of America (VOA) covered all Space Shuttle launches live from the Kennedy Space Center and provided continuing coverage of the missions from Cape Canaveral and the Johnson Space Center. In missions with foreign participation, VOA used several of its 41 foreign language services. VOA's Science Editor prepared preflight reports for each mission, and a Los Angeles-based correspondent covered the Shuttle landings. In 1985, VOA broadcast interviews with most of the astronauts, including Arab astronaut Sultan Salman, French astronaut Patrick Baudry, and three European scientists who manned Germany's Spacelab mission in October. A number of VOA features dealt with topics about space, among them "Comparing U.S. and Soviet Manned Space Programs" and "Detecting Volcanoes from Space," and a popular program with renowned astronomer Carl Sagan, which allowed VOA listeners worldwide to ask questions by telephone. The VOA continually receives requests from listeners for information on the U.S. space program. Reflecting this interest, VOA's *Voice* magazine, received by 100,000 people worldwide, carried a cover story on the Space Shuttle in its April/May issue.

Television Service

USIA's increasingly popular TV network, Worldnet, links Washington via satellite with American embassies and other organizations overseas, and often covers NASA activity. Adding a new twist to a standard news technique, Worldnet broadcast a live TV interview between King Fahd in Jidda, Saudi Arabia, and Prince Sultan Salman of Saudi Arabia, while the latter was in orbit aboard the Space Shuttle in June, 1985. Worldnet also carried a program about the future manned Space Station, that featured an interview between participants in Paris and Washington. Another interactive discussion program was on the subject of satellite communications technology and included oceanographer Jacques Cousteau, speaking from Paris; author and scientist, Arthur C. Clarke, from Sri Lanka; and others located in Washington, London, Paris, Stockholm, Rome, Madrid, and Bonn.

USIA's Satellite File – a weekly series of TV news clips used by 140 broadcasters in 99 countries – carried a number of NASA-related items, including reports about the American schoolteacher who will be a passenger on a January 1986 flight of the Shuttle, and an interview on a proposed lunar colony. The monthly television series "Science World" contained segments about the Space Station, the solar wind, and nutrition in space. A 30-minute video cassette recording (VCR) on the Space Shuttle Challenger was produced for presentation in the Agency's Information Centers in Eastern European posts. As in the past, these public showings attracted large crowds of viewers. Films and VCR's acquired from NASA, such as "Space Station: The Next Logical Step," have been consistently popular with audiences at posts worldwide.

Other Information Activities

USIA's Press and Publications Service offered a continuing stream of textual materials on U.S. space ventures to American missions abroad for placement in local media, for use in post publications, and for background information used in discussions with local opinion leaders and government officials. The Wireless File news service covered each Space Shuttle mission and supplemented that coverage with frequent photographs and article reprints from American magazines. USIA commissioned and wrote articles for periodicals, reprinted stories from the U.S. press, offered interviews of astronauts, and reviewed books and films about the space program. For example, *American Illustrated,* the monthly Russian-language magazine distributed in the Soviet Union under a reciprocal cultural agreement, and the magazines *Topic* and *Economic Impact* carried stories on various aspects of the Space Shuttle. All told, material about America's space program was sent to 214 offices in 134 nations and jurisdictions. USIA's Foreign Press Centers in Washington and Los Angeles also hosted briefings by NASA specialists for resident and visiting foreign journalists, and offered assistance to overseas correspondents interested in covering Shuttle launches and landings.

This was an active year for USIA exhibits on space. The American exhibition at Vancouver's Expo '86 will focus on the Space Station. Astronaut Dr. Joseph Allen was guest of honor at the opening of the Expo Center in Vancouver, which offered a summer-long preview of Expo '86. In addition, there were 14 showings of lunar samples in eight countries, as well as exhibits in Vienna and Caracas highlighting food for space flights.

The American Participant program, which generated extensive media coverage, sent six astronauts to as many countries for meetings and public appearances. John Blaha visited Milan's International Photographic Show and the Flanders Technology Fair in Belgium. George Nelson and Frederick Gregory attended international conferences in Nairobi, while Jeffrey Hoffman scored a public relations triumph in Lisbon, following President Reagan's visit to Portugal. Ronald McNair visited Jamaica at that government's invitation, and Robert Parker went to Indonesia to help select the first Indonesian to fly in the Space Shuttle as a Payload specialist.

Appendixes

APPENDIX A-1

U.S. Spacecraft Record

(Includes spacecraft from cooperating countries launched by U.S. launch vehicles.)

Calendar Year	Earth Orbit[a]		Earth Escape[a]	
	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2
1962	55	12	4	1
1963	62	11	0	0
1964	69	8	4	0
1965	93	7	4	1
1966	94	12	7	1[b]
1967	78	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1
1972	33	2	8	0
1973	23	2	3	0
1974	27	2	1	0
1975	30	4	4	0
1976	33	0	1	0
1977	27	2	2	0
1978	34	2	7	0
1979	18	0	0	0
1980	16	4	0	0
1981	20	1	0	0
1982	21	0	0	0
1983	31	0	0	0
1984	35	3	0	0
1985	37	1	0	0
Total	1,101	138	79	15

[a] The criterion of success or failure used is attainment of Earth orbit or Earth escape rather than judgment of mission success. "Escape" flights include all that were intended to go to at least an altitude equal to lunar distance from the Earth.
[b] This Earth-escape failure did attain Earth orbit and therefore is included in the Earth-orbit success totals.

APPENDIX A-2

World Record of Space Launches Successful in Attaining Earth Orbit or Beyond

(Enumerates launches rather than spacecraft; some launches orbited multiple spacecraft.)

Calendar Year	United States	U.S.S.R.	France	Italy	Japan	People's Republic of China	Australia	United Kingdom	European Space Agency	India
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[a]	1	1				
1971	30	83	1	2[a]	2	1		1		
1972	30	74		1	1					
1973	23	86								
1974	22	81		2[a]	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	
1980	13	89			2					1
1981	18	98			3	1			2	1
1982	18	101			1	1				
1983	22	98			3	1			2	1
1984	22	97			3	3			4	
1985	17	98			2	1			3	
Total	853	1,831	10	8	29	15	1	1	12	3

[a] Includes foreign launches of U.S. spacecraft.

Successful U.S. Launches—1985

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jan. 24 Space Shuttle Discovery (STS-51C) 10A	Objective: To launch and return Shuttle successfully, carry out assigned experinemts. Spacecrtaft: Shuttle orbiter carrying DoD experiments.	Not available	Fifteenth flight of Space Transportation System. Pilots Thomas K. Mattingly, Loren J. Shriver. Mission specialists Ellison S. Onizuka, James F. Buchli. Payload specialist Gary E. Payton. Unannounced payload included Inertial Upper Stage. Shuttle launched from KSC 2:50 p.m., EST, Discovery landed at KSC 4:23 p.m., EST. Mission time: 3 days 1 hour 33 minutes.
Jan. 24 DoD 10B	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	In orbit.
Feb. 8 DoD 14A Titan IIIB/ Agena D	Objective: Development of spacecraft technology and techniques. Spacecraft: Not announced.	Not available	In orbit.
Mar. 13 GEOSAT 21A Atlas E	Objective: To measure accurately small variations in ocean surface height. Spacecraft: Not announced.	814 757 100.6 108.1	Launched from WSMC. Still in orbit.
Mar. 22 Intelsat V-A F-10 25A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 13,500 two-way voice circuits plus two television channels. Spacecraft: Three-axis stabilized, 22 feet high, 51 feet wide, measured across solar panels. Weight: 4,402 lb. at separation from Centaur.	35,776 35,787 1,398.1 0.4	Launched from ESMC, by NASA for International Telecommunications Satellite Organization (INTELSAT). Apogee motor fired Mar. 24, placing spacecraft in synchronous equatorial orbit. First in a series of six improved INTELSAT commercial communications satellites.
Apr. 12 Space Shuttle Discovery (STS-51D) 28A	Objective: To successfully launch two communications satellites, Telesat-1 and Syncom IV-3, complete assigned experiments and objectives. Spacecraft: Shuttle orbiter carrying two satellites, two Get Away Specials (GAS), Continuous Flow Electrophoresis System (CFES III), American Flight Echocardiograph (AFE), two student experiments. Weight: 24,531 lb.	464 319 92.4 28.5	Sixteenth flight of Space Transportation System. Pilots Karol J. Bobko, Donald E. Williams, Mission specialists M. Rhea Seddon, S. David Griggs, Jeffrey A. Hoffman, Payload specialists Charles D. Walker, Senator E. J. "Jake" Garn. Shuttle lifted off from KSC 8:59 a.m., EST. Discovery landed at KSC 8:45 a.m., EST, April 19. Total mission time 6 days 23 hours 55 minutes. First flight of U.S. Senator as Payload specialist. Syncom satellite successfully deployed but did not achieve orbit despite attempts by crew to start spacecraft sequencer.
Apr. 12 Telesat-I (Anik C-1) 28B	Objective: To successfully launch satellite into transfer orbit of sufficient accuracy to allow spacecraft to achieve synchronous orbit. Spacecraft: Cylindrical. Weight: 2,557 lb.	35,798 35,777 1,436.1 2.3	Successfully deployed from Discovery. Apogee Kick Motor (AKM) fired 6:30 p.m., EST, Apr. 14.

Successful U.S. Launches—1985

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Apr. 13 Syncom IV-3 38C	Objective: To launch satellite into transfer orbit. Spacecraft: Cylindrical, telescoping satellite. Weight: 7,900 lb.	35,970 35,594 1,435.9 3.2	Syncom deployed successfully, but sequencer failed to start. Rendezvous with Discovery attempted but failed to operate sequencer lever. Satellite remained inoperable until restarted by crew of STS-51I, Sep. 1.
Apr. 29 Space Shuttle Challenger (STS-51B) 34A	Objective: To carry Spacelab 3, reusable research facility and return to earth. Deploy Northern Utah Satellite (NUSAT), Global Low Orbiting Message Relay Satellite (GLOMR). Spacecraft: Shuttle orbiter carrying two small satellites and Spacelab 3 long habitable module including 15 investigations in materials, fluid mechanics, atmospheric physics, astronomy, and life sciences. Weight: 23,474 lb.	358 345 91.6 57.0	Seventeenth flight of Space Transportation System. Piloted by Robert F. Overmyer, Frederick D. Gregory. Mission specialists: Don L. Lind, Norman E. Thagard, William E. Thornton. Payload specialists: Lodewijk Vandenberg, Taylor Wang. Shuttle launched from KSC, 12:02 p.m., EDT. Orbiter landed at Edwards, CA, 9:11 a.m., PDT, May 6. Total mission time 168 hours 9 minutes. Originally planned to return to KSC. Global Low Orbiting Message Relay Satellite (GLOMR) failed to deploy and returned to Earth with orbiter.
Apr. 29 NUSAT-1 (Northern Utah Satellite) 34B	Objective: To launch satellite into successful orbit. Spacecraft: 26-sided polyhedron, with six-month design life. Weight: 115 lb.	339 318 91.1 57.0	Successfully deployed from Challenger. In orbit.
June 17 Space Shuttle Discovery (STS-51G) 48A	Objective: To launch MORELOS-A, Arabsat 1B, Telstar 3D, and launch and retrieve Spartan 1. Spacecraft: Shuttle orbiter carrying satellites, as well as experiments Automated Directional Solidification Furnance (ADSF), French Echocardiograph Experiment (FEE), French Postural Experiment (FPE), Arabsat Scientific Experiments (ASE), six Getaway Specials (GAS).	391 355 90.2 28.5	Eighteenth flight of Space Transportation System. Piloted by Daniel C. Brandenstein, John O. Creighton. Mission specialist: Shannon W. Lucid, John M. Fabian, Steven R. Nagel. Payload specialist: Patrick Baudry (France) and Sultan bin Salman bin Abdul-Aziz Al-Saud (Saudia Arabia). Shuttle launched from KSC at 7:33 a.m., EDT. Deployed satellites, carried out experiments. Discovery landed on runway 23 at Edwards AFB, CA, 6:13 a.m., PDT, June 24. Total mission time 7 days, 1 hour, and 39 minutes. Orbiter returned to KSC for refurbishment for next launch.
June 17 MORELOS A 48B	Objective: To launch satellite into transfer orbit permitting spacecraft propulsion system to place it in stationary synchronous orbit for communications coverage. Spacecraft: Cylindrical, spin-stabilized. Height in launch configuration: 9 feet, 4 inches. Weight in orbit: 1,422 lb.	35,798 35,776 1,436.1 0.0	Successfully deployed from Discovery June 17 at 3:38 p.m., EDT, Apogee Kick Motor (AKM) fired 7:49 a.m., EDT, June 18. In geosynchronous orbit.

Successful U.S. Launches—1985

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
June 18 Arabsat 1B 48C	Objective: To launch satellite into transfer orbit of sufficient accuracy to allow spacecraft propulsion systems to place it in stationary synchronous orbit for communications coverage. Spacecraft: Rectangular with deployable solar arrays. Weight: 2,800 lb.	35,833 35,737 1,436.1 0.0	Successfully deployed from Discovery June 18 at 9:56 a.m., EDT. In synchronous orbit at 26° east longitude.
June 19 Telstar 3D 48D	Objective: To launch satellite into planned orbit. Spacecraft: Cylindrical, spin-stabilized. Weight: 3,402 kg.	35,791 35,783 1,436.1	Successfully deployed June 19 at 7:20 a.m., EDT, with AKM burn on June 21. In orbit at 125° west longitude.
June 20 Spartan 1 48E	Objective: To launch and retrieve Spartan 1. Satellite to map x-ray emissions from stars, and provide engineering data on Spartan concept. Spacecraft: Rectangular, 126 by 42 by 48 inches. Weight: 2,223 lb., including 300 lb. of experiments. Instrument provided by U.S. Naval Research Laboratory.	Not available	Successfully deployed, first in series of low-cost free flyers designed to extend capabilities of sounding rocket class experiments. Retrieved June 24 and returned to Earth with Discovery.
June 30 Intelsat V-A F-11 55A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 13,500 two-way voice circuits plus two television channels. Spacecraft: Three-axis stabilized, 22 feet high and 51 feet wide, measured across solar panels. Weight: 2,430 lb. in geosynchronous orbit.	35,774 34,401 1,400.6 0.1	Second in a series of improved INTELSAT commercial communications satellite launched by NASA from the ESMC. Moved to final orbit at 332.5 degrees east longitude by Aug. 25.
Jul. 29 Space Shuttle Challenger (STS-51F) 63A	Objective: To carry Spacelab-2 aboard Shuttle, to launch and retrieve Plasma Diagnostic Package (PDP). Spacecraft: Shuttle orbiter carrying igloo-pallet configuration with Spacelab-2 experiments: Solar Magnetic and Velocity Field Measurement System/Solar Optical Universal Polarimeter (SOUP), Coronal Helium Abundance Spacelab Experiment (CHASE), Solar Ultraviolet High Resolution Telescope and Spectrograph (HRTS), Solar Ultraviolet Spectral Irradiance Monitor (SUSIM), Vehicle Charging and Potential Experiment (VCAP), Plasma Depletion Experiments for Ionospheric and Radio Astronomical Studies, Elemental Composition and Energy Spectra of Cosmic Ray Nuclei Between GeV/Nucleon and Several TeV/Nucleon (CRN), Hard X-Ray Imaging of Clusters of Galaxies and Other Extended X-Ray Sources/X-Ray Telescope (XRT), Small Helium-Cooled Infrared Telescope (IRT), Properties of Superfluid Helium in Zero-Gravity, Vitamin D Metabolites and Bone Demineralization, Gravity-Influenced Lignification in Higher Plants/Plant Growth Unit (PGU). Additional experiments: Protein Crystal Growth, Plant Growth Unit (PGU). Shuttle Amateur Radio Experiment (SAREX), Carbonated Beverage Dispenser Evaluation (CBDE). Weight of Spacelab-2 payload: 33,145 lb.	321 312 90.5 49.5	Nineteenth flight of space Transportation System. Piloted by Charles G. Fullerton and Roy D. Bridges, Jr. Mission specialist: Karl G. Henize, Anthony W. England, and F. Story Musgrave. Payload specialists: Loren W. Acton and John-David F. Bartow. Lift-off from KSC at 5:00 p.m., EDT July 29. PDP deployed and retrieved, Spacelab-2 experiments conducted successfully. Data being evaluated. Challenger landed at Edwards AFB, CA, 3:45 p.m., EDT, Aug. 6. Mission duration: 7 days, 22 hours and 45 minutes. Orbiter returned to KSC for next flight.

Successful U.S. Launches—1985

Launch Date (GMT), Spacecraft Name, COSPAR Designation Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jul. 29 Plasma Diagnostic Package (PDP) 63B	Objective: To deploy and retrieve Experiment. Spacecraft: Not available.	Same as orbiter.	Satellite launched by Challenger Aug. 1. Experiments successfully conducted and spacecraft retrieved six hours later for return to Earth and future reuse.
Aug. 3 Oscar 24 66A Scout	Objective: To successfully launch satellite. Spacecraft: Not available.	1,259 1,001 107.9 89.8	Launched from WSMC, part of Navy Transit (Navy Navigational Satellite System). In orbit.
Aug. 3 Oscar 30 66B	Objective: To successfully launch satellite. Spacecraft: Not available.	1,260 1,000 107.9 89.8	Successfully launched from WSMC for Navy Transit program. In orbit.
Aug. 27 Space Shuttle Discovery (STS-51I) 76A	Objective: To successfully launch three communications satellites, ASC-1, AUSSAT-1, and Syncom IV-4; to repair Syncom IV-3; complete assigned experiments and objectives. Spacecraft: Shuttle orbiter carrying three satellites, and Physical Vapor Transport and Organic Solids (PVTOS) experiment.	190 190 90 28.45	Twentieth flight of Space Transportation System. Pilots Joe H. Engle, Richard O. Covey. Mission specialists James D. van Hoften, William F. Fisher, John M. Lounge. Discovery departed KSC 6:58 a.m., EDT. Landed at Edwards, CA runway 23, 9:16 a.m., EDT, Sep. 3. Mission duration 7 days 2 hours 18 minutes. Mission specialists van Hoften and Fisher successfully repaired Syncom IV-3 (launched Apr. 13 by STS-51D).
Aug. 27 AUSSAT-1 76B	Objective: To successfully launch communications satellite. Spacecraft: Cylindrical, 7.2 feet in diameter, 9.2 high in stowed position. In orbit with antenna and solar panel deployed 21.6 m. high. Weight in orbit: 1,322 lb.	35,795 35,779 1,436.2 0.0	Successfully deployed from Discovery, for Australia's National Satellite Company. Satellite on orbit and functioning.
Aug. 27 ASC-1 76C	Objective: To successfully launch communications satellite. Spacecraft: Box-shaped, 4.3 by 5.3 by 10.5 feet in cargo bay. On orbit with solar panels deployed 46.5 feet in length. Weight in orbit: 1,482 lb.	35,791 35,782 1,436.1 0.1	Successfully deployed from Discovery, for American Satellite Company. In geosynchronous orbit.
Aug. 29 Syncom IV-4 76D	Objective: To launch satellite into successful transfer orbit. Spacecraft: Cylindrical, telescoping satellite. Weight in cargo bay: 17,000 lb.	35,791 35,787 1,436.2 3.2	Successfully launched from Discovery for U.S. Navy (Leasat-4). Replacement for FleetSatCom spacecraft. Syncom IV-4, although in correct geosynchronous orbit, ceased functioning.
Sep. 29 Intelsat V-A F-12 87A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 13,500 two-way voice circuits plus two television channels. Spacecraft: Three axis stabilized, 22 feet high, 51 feet wide, measured across solar panels. Weight at launch: 4,402 lb.	35,805 35,776 1410.9 0.2	Last INTELSAT commercial communications satellite to be launched by NASA for INTELSAT from ESMC. Satellite to be assigned to the Indian Ocean region, replacing INTELSAT V F-1.

Successful U.S. Launches—1985

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Oct. 3 Space Shuttle Atlantis (STS-51J) 92A	Objective: To launch DoD satellites, conduct experiments. Spacecraft: Shuttle orbiter carrying DoD experiments and satellites.	Not available	Twenty-first flight of Space Transportation System. Pilots Karol J. Bobko, Ronald J. Grabe. Mission specialists Robert A. Stewart, David C. Hilmers, Payload specialist William A. Pailes, Atlantis launched from KSC 11:15 A.M., EDT, landed runway 23, Edwards, CA, 1:00 P.M., EDT, Oct. 7. Mission duration 4 days, 1 hour 45 minutes.
Oct. 3 DoD 92B	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	In orbit.
Oct. 3 DoD 92C	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	Not available	In orbit.
Oct. 9 Navstar-11 93A Atlas E	Objective: To launch satellite into planned orbit. Spacecraft: Same basic configuration as Navstar-8, launched in 1983. Weight: 873 kg.	20,532 19,729 717.9 63.4	Global Positioning System satellite launched by DoD in joint military services' developmental network. Still in orbit.
Oct. 30 Space Shuttle Challenger (STS-61A) 104A	Objective: To launch Spacelab D-1, conduct experiments, deploy Global Low Orbiting Message Relay Satellite (GLOMR). Spacecraft: Shuttle orbiter carrying Spacelab D-1 long module plus Mission Peculiar Equipment Support Structure. Weight: 30,541 lb.	333 321 91.0 57.0	Twenty-second flight of Space Transportation System. Launched aboard Challenger for German Federal Ministry of Research and Technology (BMFT). Pilots Henry W. Hartsfield, Steven R. Nagel. Mission specialists Bonnie J. Dunbar, James F. Buchli, Guion S. Bluford. Payload specialists Ernst Messerschmind (Germany), Reinhard Furrer (Germany), Wubbo J. Ockels (Dutch). Challenger lifted off KSC 12:00 p.m., EST, landed runway 17, Edwards, CA, 12:45 p.m., EST, Nov. 6. Mission time 7 days 45 minutes.
Oct. 30 GLOMR 104B	Objective: To successfully launch satellite. Spacecraft: 62-sided polyhedron. Weight: 150 lb.	333 318 91.0 57.0	Successfully launched from Challenger. In orbit.
Nov. 27 Space Shuttle Atlantis (STS-61B) 109A	Objective: To launch MORELOS-B, AUSSAT-2, Satcom KU-2, and conduct experiments. Spacecraft: Shuttle orbiter carrying satellites, as well as experiments Experimental Assembly of Structures with Extravehicular Activity (EASE), Assembly Concept for Construction of Erectable Space Structure (ACCESS), IMAX Camera, Continuous Flow Electrophoresis System (CFES III), Diffusive Mixing of Organic Solutions (DMOS), Morelos Payload Specialists Experiments (MPSE), 1 Getaway Special (GAS). Weight: 42,790 lb.	370 350 91.9 28.5	Twenty-third flight of Space Transportation System. Piloted by Brewster H. Shaw, Bryan D. O'Connor. Mission specialists Mary L. Cleave, Sherwood C. Spring, Jerry L. Ross, Payload specialists Rudolfo Neri Vela, Charles D. Walker. Atlantis launched KSC 7:29 p.m., EST. Satellites deployed and experiments conducted, Shuttle landed on runway 17, Edwards, CA, 6:23 p.m., EST Dec. 3. Mission time 6 days 22 hours 54 minutes. Orbiter returned to KSC for next flight.

Successful U.S. Launches—1985

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Nov. 27 MORELOS-B 109B	Objective: To successfully launch communications satellite. Spacecraft: Cylindrical, spin-stabilized, in orbit, with antenna and solar panels extended 21 feet 8 inches high, 7 feet 1 inch in diameter. Weight: 10,008 lb.	35,801 35,773 1,436.1 2.9	Successfully launched from Atlantis. Second of two satellites launched for Secretariat of Communications and Transportation, Mexico. To serve as on station space for MORELOS-A. In orbit.
Nov. 27 AUSSAT-2 109C	Objective: To launch satellite into successful transfer orbit. Spacecraft: Cylindrical, in orbit with antenna and solar panels deployed 21.6 m high and 7.2 feet in diameter. Weight in orbit: 1,322 lb.	35,790 35,786 1,436.2 0.1	Second in series of three communications satellites successfully launched for the Australian National Satellite Communications System, at 8:20 p.m., EST. In orbit.
Nov. 28 RCA Satcom K-2 109D	Objective: To launch communications satellite successfully. Spacecraft: Box-shaped, 67 by 84 by 60 inch main structure, spin-stabilized, solar panels of two deployable arms. Weight before launch: 15, 929 lb.	35,801 35,774 1,436.2 0.1	Successfully deployed from Atlantis, second in series of three satellites for RCA American Communications, Inc. In orbit.
Dec. 13 Defense 114A Scout	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	776 314 95.6 37.1	Launched from Wallops Flight Facility by NASA for the Air Force.
Dec. 13 Defense 114B	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced	772 314 95.5 37.1	Launched from Wallops Flight Facility by NASA for the Air Force.

U.S.-Launched Applications Satellites 1979–1985

Date	Name	Launch Vehicle	Remarks
		COMMUNICATIONS	
May 4, 1979	Fltsatcom 2	Atlas-Centaur	Second of new DoD series.
Aug. 9, 1979	Westar 3	Thor-Delta (TAT)	Launched for Western Union Co. as part of its 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.
Jan. 18, 1980	Fltsatcom 3	Atlas-Centaur	Third of DoD series.
Oct. 31, 1980	Fltsatcom 4	Atlas-Centaur	Fourth of DoD series.
Nov. 15, 1980	SBS 1	Thor-Delta (TAT)	Launched for Satellite Business Systems as part of its domestic communications links.
Dec. 6, 1980	Intelsat V F-2	Atlas-Centaur	First of new series, positioned over Atlantic.
Feb. 21, 1981	Comstar D-4	Atlas-Centaur	Fourth in series for Comsat General Corp.
May 23, 1981	Intelsat V F-1	Atlas-Centaur	Second in series for INTELSAT, positioned over Atlantic.
Aug. 6, 1981	Fltsatcom 5	Atlas-Centaur	Fifth in DoD series.
Sept. 24, 1981	SBS 2	Thor-Delta (TAT)	Second in series for Satellite Business Systems.
Nov. 20, 1981	RCA-Satcom 3-R	Thor-Delta (TAT)	Fourth in series for RCA, replacement for RCA-Satcom 3.
Dec. 15, 1981	Intelsat V F-3	Atlas-Centaur	Third in series. To be positioned over Atlantic.
Jan. 16, 1982	RCA-Satcom 4	Thor-Delta (TAT)	Fifth in series for RCA.
Feb. 26, 1982	Westar 4	Thor-Delta (TAT)	First in a series of second-generation for Western Union Co.
Mar. 5, 1982	Intelsat V F-4	Atlas-Centaur	Fourth in series; positioned over Pacific.
Apr. 10, 1982	Insat 1A	Thor-Delta (TAT)	First in series for India Department of Space.
June 9, 1982	Westar 5	Thor-Delta (TAT)	Second in series of second-generation for Western Union Co.; replaces Westar 2.
Aug. 26, 1982	Anik D-1	Thor-Delta (TAT)	Launched for Telesat Canada as replacement for in-orbit satellites.
Sept. 28, 1982	Intelsat V F-5	Atlas-Centaur	Fifth in series; positioned over Indian Ocean.
Oct. 27, 1982	RCA-Satcom 5	Thor-Delta (TAT)	Joined 4 operational satellites launched for RCA.
Oct. 30, 1982	DSCS II, DSCS III	Titan III(34) D/IUS	Defense communications (dual launch), including first in series of uprated satellites.
Nov. 11, 1982	SBS 3	Space Shuttle, PAM-D	Third in series for Satellite Business Systems.
Nov. 12, 1982	Anik C-3	Space Shuttle, PAM-D	Second in new series for Telesat Canada.
Apr. 4, 1983	TDRS 1	Space Shuttle, IUS	First in series. System to provide continuous satellite communication. Leased by NASA from Space Communications Co. (Spacecom).
Apr. 11, 1983	RCA-Satcom 6	Delta 3924	Replacement for RCA-Satcom 1, launched for RCA.
May 19, 1983	Intelsat V F-6	Atlas-Centaur	Sixth in series; positioned over Atlantic Ocean.
June 18, 1983	Anik C-2	Space Shuttle, PAM-D	Launched for Telesat Canada.
June 19, 1983	Palapa B-1	Space Shuttle, PAM-D	Indonesian domestic communications.
June 28, 1983	Galaxy 1	Delta 3920/PAM-D	Launched for Hughes Communications, Inc.
July 28, 1983	Telstar 3A	Delta 3920/PAM-D	Launched for American Telephone and Telegraph Co.
Aug. 31, 1983	Insat 1-B	Space Shuttle, PAM-D	Indian domestic communications.
Sept. 8, 1983	RCA-Satcom 7	Delta 3924	Replacement for RCA-Satcom 2, launched for RCA.
Sep. 22 1983	Galaxy 2	Delta 3920/PAM-D	Second in series, launched for Hughes Communications, Inc.
Feb. 3, 1984	Westar-6	Space Shuttle, PAM-D	Launched for Western Union, PAM-D failed to fire properly, satellite retrieved by Shuttle, and returned to earth for refurbishment.
Feb. 6, 1984	Palapa-B2	Space Shuttle, PAM-D	Launched for Indonesia, booster motor failed, satellite retrieved and returned to earth by Shuttle.
Mar. 1, 1984	Uosat-2	Delta 3920	Secondary payload with Landsat-5, for amateur radio communications.
June 9, 1984	Intelsat V F-9	Atlas-Centaur	Seventh in series, launch vehicle failure, satellite reentered Oct. 24.
Aug. 31, 1984	SBS-4	Space Shuttle, PAM-D	Launched for Satellite Business Systems, Inc.
Aug. 31, 1984	Syncom IV-2	Space Shuttle	Launched for Hughes Communication Service, Inc.
Sept. 1, 1984	Telstar-3C	Space Shuttle, PAM-D	Launched for American Telephone and Telegraph Co.
Sept. 21, 1984	Galaxy-3	Dalta 3920/PAM-D	Third in series, launched for Hughes Communications, Inc.
Nov. 9, 1984	Anik-D2	Space Shuttle, PAM-D	Launched for Telsat Canada.

U.S.-Launched Applications Satellites 1979-1985

Date	Name	Launch Vehicle	Remarks
Nov. 10, 1984	Syncom IV-1	Space Shuttle	Launched for Hughes Communication Service, Inc.
Nov. 14, 1984	NATO IIID	Delta 3914	NATO defense-related communications satellite.
Mar. 22, 1985	Intelsat VA F-10	Atlas-Centaur	First in series of six improved satellites.
Apr. 12, 1985	Telesat-I	Space Shuttle	Launched for Telsat Canada.
Apr. 13, 1985	Syncom IV-3	Space Shuttle	Launched for US Navy.
June 17, 1985	MORELOS-A	Space Shuttle	Launched for Mexico.
June 18, 1985	Arabsat-1B	Space Shuttle	Launched for Arab Satellite Communication Organization (ASCO).
June 19, 1985	Telstar-3D	Space Shuttle	Launched for the American Telephone and Telegraph Company (AT&T).
June 30, 1985	Intelsat VA F-11	Atlas-Centaur	Second in series of improved satellites launched for INTELSAT.
Aug. 27, 1985	AUSSAT-1	Space Shuttle	Launched for Australia's National Satellite Company.
Aug. 27, 1985	ASC-1	Space Shuttle	Launched for American Satellite Company.
Aug. 29, 1985	Syncom IV-4	Space Shuttle	Launched for US Navy.
Sep. 29, 1985	Intelsat VA F-12	Atlas-Centaur	Launched for INTELSAT.
Nov. 27, 1985	MORELOS-B	Space Shuttle	Launched for Mexico.
Nov. 27, 1985	AUSSAT-2	Space Shuttle	Second satellite launched for Australia's National Satellite Company.
Nov. 28, 1985	RCA Satcom K-2	Space Shuttle	Launched for RCA American Communications, Inc.
			WEATHER OBSERVATION [a]
June 6, 1979	AMS 4	Atlas F	DoD meteorological satellite.
June 27, 1979	NOAA 6	Atlas F	Second of 8 planned third-generation satellites for NOAA; first was Tiros-N.
May 29, 1980	NOAA-B	Atlas F	Failed to achieve useful orbit.
Sept. 9, 1980	GOES 4	Thor-Delta (TAT)	Fourth of this series for NOAA.
May 22, 1981	GOES 5	Thor-Delta (TAT)	Fifth of polar-orbiting series for NOAA.
June 23, 1981	NOAA 7	Atlas F	Replacement for NOAA-B.
Dec. 21, 1982	DMSP F-6	Atlas E	DoD meterological satellite.
Mar. 28, 1983	NOAA 8	Atlas E	Joined NOAA 7 as part of 2-satellite operational system; launched for NOAA.
Apr. 28, 1983	GOES 6	Delta 3914	Launched for NOAA, operational as GOES-West.
Nov. 18, 1983	DMSP F-7	Atlas E	Second in block 5D-2 series, DoD meteorological satellite.
Dec. 12, 1984	NOAA-9	Atlas E	Launched for NOAA, to replace NOAA-7.
			EARTH OBSERVATION
July 16, 1982	Landsat 4	Thor-Delta (TAT)	Fourth experimental earth resources satellite. First use of thematic mapper (TM).
Mar. 1, 1984	Landsat-5	Delta 3920	Fifth experimental earth resources satellite, to replace ailing Landsat-4.
			GEODESY
Mar. 13, 1985	GEOSAT	Atlas E	Measure ocean surface height.
			NAVIGATION
Feb. 9, 1980	Navstar 5	Atlas F	Global Positioning System satellite.
Apr. 26, 1980	Navstar 6	Atlas F	Global Positioning System satellite.
May 15, 1981	Nova 1	Scout	First of improved Transit system satellites, for DoD.
July 14, 1983	Navstar 8	Atlas E	Global Positioning System satellite.
Feb. 5, 1984	IRT	Space Shuttle	Balloon to test Shuttle rendezvous radar.
June 13, 1984	Navstar-9	Atlas E	Global Positioning System satellite.
Sept. 8, 1984	Navstar-10	Atlas E	Global Positioning System satellite.
Oct. 12, 1984	Nova-3	Scout	Second of improved Transit system satellites, for DoD.
Aug. 3, 1985	Oscar 24	Scout	Part of Navy Transit System.
Aug. 3, 1985	Oscar 30	Scout	Part of Navy Transit System.
Oct. 9, 1985	Navstar-11	Atlas E	Global Positioning System satellite.

[a] Does not include Department of Defense weather satellites that are not individually identified by launch.

U.S.-Launched Scientific Satellites 1979-1985

Date	Name	Launch Vehicle	Remarks
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).
Sept. 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.
Feb. 14, 1980	SMM	Thor-Delta (TAT)	Solar Maximum Mission.
Aug. 3, 1981	Dynamics Explorers 1, 2	Thor-Delta (TAT)	DE 1 and 2 to measure magnetospheric-ionospheric energy coupling, electric currents and fields, plasmas.
Oct. 6, 1981	SME	Thor-Delta (TAT)	Solar Mesosphere Explorer to measure changes in mesospheric ozone.
Oct. 6, 1981	UOSAT (Oscar 9)	Thor-Delta (TAT)	Secondary payload with SME, for amateur radio and science experiments.
Jan. 26, 1983	IRAS	Delta 3910	Infrared sky survey.
May 26, 1983	EXOSAT	Delta 3914	European Space Agency study of x-ray sources.
June 22, 1983	SPAS 01	Space Shuttle	Reusable free-flying platform deployed and retrieved during STS 7; 6 scientific experiments from West Germany, 2 from ESA. NASA experiments tested spacecraft technology.
June 27, 1983	HILAT (P83-1)	Scout	Propagation effects of disturbed plasma on radar and communication systems, for DoD.
Apr. 6, 1984	Long Duration Exposure Facility (LDEF-1)	Space Shuttle	Scientific experiments designed for retrieval from space by Shuttle.
Aug. 16, 1984	Charge Composition Explorer (CCE)	Delta 3924	Measurement of earth's magnetosphere, one of three satellites composing Active Magnetosphere Particle Tracer Explorers Mission (AMPTE).
Aug. 16, 1984	Ion Release Module (IRM)	Delta 3924	Second of three satellites of AMPTE Mission, launched by same vehicle.
Aug. 16, 1984	United Kingdom Satellite (UKS)	Delta 3924	Third of three satellites of AMPTE Mission, launched by same vehicle.
Oct. 5, 1984	Earth Radiation Budget Satellite (ERBS)	Space Shuttle	First of three satellites in Earth Radiation Budget Experiment Research Program, NOAA-9 and NOAA-G carrying other instruments in Program.
Apr. 29, 1985	NUSAT-1	Space Shuttle	Northern Utah Satellite (air traffic control radar system calibrator).
June 20, 1985	Spartan-1	Space Shuttle	Reusable free-flying platform.
July 29, 1985	Plasma Diagnostic Package (PDP)	Space Shuttle	Reusable experimental platform.
Oct. 30, 1985	GLOMR	Space Shuttle	Global Low Orbiting Message Relay satellite.

U.S.-Launched Space Probes 1975–1985

Date	Name	Launch Vehicle	Remarks
Aug. 20, 1975	Viking 1	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Chryse, Sept. 6 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of atmosphere.
Sept. 9, 1975	Viking 2	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Utopia, July 20, 1976, while orbiter circled 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 Sun, measuring solar wind, corona, electrons, and cosmic rays. Payload had same West German and U.S. experiments as Helios 1 plus cosmic-ray burst detector.
Aug. 20, 1977	Voyager 2	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Swung around Jupiter in July 1979, arrived Saturn in 1981, going on to Uranus by 1986, Neptune by 1989.
Sep. 5, 1977	Voyager 1	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Passing Voyager 2 on the way, swung around Jupiter in Mar. 1979, arrived at Saturn in Nov. 1980, headed for outer solar system.
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.
None in 1984			
None in 1985			

U.S. and Soviet Manned Spaceflights 1961-1985

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Vostok 1	Apr. 12, 1961	Yuriy A. Gagarin	0 : 1 : 48	First manned flight.
Mercury-Redstone 3	May 5, 1961	Alan B. Shepard, Jr.	0 : 0 : 15	First U.S. flight; suborbital.
Mercury-Redstone 4	July 21, 1961	Virgil I. Grissom	0 : 0 : 16	Suborbital; capsule sank after landing; astronaut safe.
Vostok 2	Aug. 6, 1961	German S. Titov	1 : 1 : 18	First flight exceeding 24 h.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	0 : 4 : 55	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	0 : 4 : 56	Landed 400 km beyond target.
Vostok 3	Aug. 11, 1962	Andriyan G. Nikolayev	3 : 22 : 25	First dual mission (with Vostok 4).
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	2 : 22 : 59	Came within 6 km of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	0 : 9 : 13	Landed 8 km from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	1 : 10 : 20	First U.S. flight exceeding 24 h.
Vostok 5	June 14, 1963	Valeriy F. Bykovskiy	4 : 23 : 6	Second dual mission (with Vostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	2 : 22 : 50	First woman in space; within 5 km of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Boris G. Yegorov	1 : 0 : 17	First 3-man crew.
Voskhod 2	Mar. 18, 1965	Pavel I. Belyayev Aleksey A. Leonov	1 : 2 : 2	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	0 : 4 : 53	First U.S. 2-man flight; first manual maneuver in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White II	4 : 1 : 56	21-min extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	7 : 22 : 55	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	13 : 18 : 35	Longest-duration manned flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	1 : 1 : 51	Rendezvous within 30 cm of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	0 : 10 : 41	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	3 : 0 : 21	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	2 : 22 : 47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	2 : 23 : 17	First initial-orbit docking; first tethered flight; highest Earth-orbit altitude (1,372 km).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	3 : 22 : 35	Longest extravehicular activity to date (Aldrin, 5 hrs 37 min).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	1 : 2 : 37	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	10 : 20 : 9	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgiy T. Beregovoy	3 : 22 : 51	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	6 : 3 : 1	First manned orbit(s) of moon; first manned departure from Earth's sphere of influence; highest speed attained in manned flight to date.
Soyuz 4	Jan. 14, 1969	Vladimir A. Shatalov	2 : 23 : 23	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris V. Volynov Aleksey S. Yeliseyev Yevgeniy V. Khrunov	3 : 0 : 56	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	10 : 1 : 1	Successfully simulated in Earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	8 : 0 : 3	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.	8 : 3 : 9	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 N. Kubasov	4 : 22 : 42	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 V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4 : 22 : 41	
Soyuz 8	Oct. 13, 1969	Vladimir A. Shatalov Aleksey S. Yeliseyev	4 : 22 : 50	

U.S. and Soviet Manned Spaceflights 1961-1985

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	10 : 4 : 36	Second manned lunar landing. Explored surface of moon and retrieved parts of Surveyor 3 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.	5 : 22 : 55	Mission aborted; explosion in service module. Ship circled moon, with crew using LM as "lifeboat" until just before reentry.
Soyuz 9	June 1, 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17 : 16 : 59	Longest manned spaceflight to date.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	9 : 0 : 2	Third manned lunar landing. Mission demonstrated pinpoint landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir A. Shatalov Aleksey S. Yeliseyev Nikolay N. Rukavishnikov	1 : 23 : 46	Docked with Salyut 1, but crew did not board space station launched 19 Apr. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy T. Dobrovolskiy Vladislav N. Volkov Viktor I. Patsayev	23 : 18 : 22	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	David R. Scott Alfred M. Worden James B. Irwin	12 : 7 : 12	Fourth manned lunar landing and first Apollo "J" series mission, which carried Lunar Roving Vehicle. Worden's inflight EVA of 38 min 12 sec was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly II	11 : 1 : 51	Fifth manned lunar landing, with Lunar Roving Vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	12 : 13 : 52	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	28 : 0 : 50	Docked with Skylab 1 (launched unmanned May 14) for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	59 : 11 : 9	Docked with Skylab 1 for more than 59 days.
Soyuz 12	Sept. 27, 1973	Vasiliy G. Lazarev Oleg G. Makarov	1 : 23 : 16	Checkout of improved Soyuz.
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	84 : 1 : 16	Docked with Skylab 1 in long-duration mission; last of Skylab program.
Soyuz 13	Dec. 18, 1973	Petr I. Klimuk Valentin V. Lebedev	7 : 20 : 55	Astrophysical, biological, and earth resources experiments.
Soyuz 14	July 3, 1974	Pavel R. Popovich Yuriy P. Artyukhin	15 : 17 : 30	Docked with Salyut 3 and Soyuz 14 crew occupied space station.
Soyuz 15	Aug. 26, 1974	Gennadiy V. Sarafanov Lev S. Demin	2 : 0 : 12	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatoliy V. Filipchenko Nikolay N. Rukavishnikov	5 : 22 : 24	Test of ASTP configuration.
Soyuz 17	Jan. 10, 1975	Aleksey A. Gubarev Georgiy M. Grechko	29 : 13 : 20	Docked with Salyut 4 and occupied station.
Anomaly	Apr. 5, 1975	Vasiliy G. Lazarev Oleg G. Makarov	0 : 0 : 20	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr I. Klimuk Vitaliy I. Sevastyanov	62 : 23 : 20	Docked with Salyut 4 and occupied station.
Soyuz 19	July 15, 1975	Aleksey A. Leonov Valeriy N. Kubasov	5 : 22 : 31	Target for Apollo in docking and joint experiments of ASTP mission.
Apollo (ASTP)	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	9 : 1 : 28	Docked with Soyuz 19 in joint experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris V. Volynov Vitaliy M. Zholobov	48 : 1 : 32	Docked with Salyut 5 and occupied station.

U.S. and Soviet Manned Spaceflights 1961-1985

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz 22	Sept. 15, 1976	Valeriy F. Bykovskiy Vladimir V. Aksenov	7 : 21 : 54	Earth resources study with multispectral camera system.
Soyuz 23	Oct. 14, 1976	Vyacheslav D. Zudov Valeriy I. Rozhdestvenskiy	2 : 0 : 6	Failed to dock with Salyut 5.
Soyuz 24	Feb. 7, 1977	Viktor V. Gorbatko Yuriy N. Glazkov	17 : 17 : 23	Docked with Salyut 5 and occupied station.
Soyuz 25	Oct. 9, 1977	Vladimir V. Kovalenok Valeriy V. Ryumin	2 : 0 : 46	Failed to achieve hard dock with Salyut 6 station.
Soyuz 26	Dec. 10, 1977	Yuriy V. Romanenko Georgiy M. Grechko	37 : 10 : 6	Docked with Salyut 6. Crew returned in Soyuz 27; crew duration 96 days 10 hrs.
Soyuz 27	Jan. 10, 1978	Vladimir A. Dzhanibekov Oleg G. Makarov	64 : 22 : 53	Docked with Salyut 6. Crew returned in Soyuz 26; crew duration 5 days 22 hrs 59 min.
Soyuz 28	Mar. 2, 1978	Aleksey A. Gubarev Vladimir Remek	7 : 22 : 17	Docked with Salyut 6. Remek was first Czech cosmonaut to orbit.
Soyuz 29	June 15, 1978	Vladimir V. Kovalenok Aleksandr S. Ivanchenkov	79 : 15 : 23	Docked with Salyut 6. Crew returned in Soyuz 31; crew duration 139 days 14 hrs 48 min.
Soyuz 30	June 27, 1978	Petr I. Klimuk Miroslaw Hermaszewski	7 : 22 : 4	Docked with Salyut 6. Hermaszewski was first Polish cosmonaut to orbit.
Soyuz 31	Aug. 26, 1978	Valeriy F. Bykovskiy Sigmund Jaehn	67 : 20 : 14	Docked with Salyut 6. Crew returned in Soyuz 29; crew duration 7 days 20 hrs 49 min. Jaehn was first German Democratic Republic cosmonaut to orbit.
Soyuz 32	Feb. 25, 1979	Vladimir A. Lyakhov Valeriy V. Ryumin	108 : 4 : 24	Docked with Salyut 6. Crew returned in Soyuz 34; crew duration 175 days 36 min.
Soyuz 33	Apr. 10, 1979	Nikolay N. Rukavishnikov Georgi I. Ivanov	1 : 23 : 1	Failed to achieve docking with Salyut 6 station. Ivanov was first Bulgarian cosmonaut to orbit.
Soyuz 34	June 6, 1979	(unmanned at launch)	73 : 18 : 17	Docked with Salyut 6, later served as ferry for Soyuz 32 crew while Soyuz 32 returned unmanned.
Soyuz 35	Apr. 9, 1980	Leonid I. Popov Valeriy V. Ryumin	55 : 1 : 29	Docked with Salyut 6. Crew returned in Soyuz 37. Crew duration, 184 days 20 hrs 12 min.
Soyuz 36	May 26, 1980	Valeriy N. Kubasov Bertalan Farkas	65 : 20 : 54	Docked with Salyut 6. Crew returned in Soyuz 35. Crew duration 7 days 20 hrs 46 min. Farkas was first Hungarian to orbit.
Soyuz T-2	June 5, 1980	Yuriy V. Malyshev Vladimir V. Aksenov	3 : 22 : 21	Docked with Salyut 6. First manned flight of new-generation ferry.
Soyuz 37	July 23, 1980	Viktor V. Gorbatko Pham Tuan	79 : 15 : 17	Docked with Salyut 6. Crew returned in Soyuz 36. Crew duration 7 days 20 hrs 42 min. Pham was first Vietnamese to orbit.
Soyuz 38	Sept. 18, 1980	Yuriy V. Romanenko Arnaldo Tamayo Mendez	7 : 20 : 43	Docked with Salyut 6. Tamayo was first Cuban to orbit.
Soyuz T-3	Nov. 27, 1980	Leonid D. Kizim Oleg G. Makarov Gennadiy M. Strekalov	12 : 19 : 8	Docked with Salyut 6. First 3-man flight in Soviet program since 1971.
Soyuz T-4	Mar. 12, 1981	Vladimir V. Kovalenok Viktor P. Savinykh	74 : 18 : 38	Docked with Salyut 6.
Soyuz 39	Mar. 22, 1981	Vladimir A. Dzhanibekov Jugderdemidiyn Gurragcha	7 : 20 : 43	Docked with Salyut 6. Gurragcha first Mongolian cosmonaut to orbit.
Space Shuttle Columbia (STS 1)	Apr. 12, 1981	John W. Young Robert L. Crippen	2 : 6 : 21	First flight of Space Shuttle, tested spacecraft in orbit. First landing of airplanelike craft from orbit for reuse.
Soyuz 40	May 14, 1981	Leonid I. Popov Dumitru Prunariu	7 : 20 : 41	Docked with Salyut 6. Prunariu first Romanian cosmonaut to orbit.
Space Shuttle Columbia (STS 2)	Nov. 12, 1981	Joe H. Engle Richard H. Truly	2 : 6 : 13	Second flight of Space Shuttle, first scientific payload (OSTA 1). Tested remote manipulator arm. Returned for reuse.
Space Shuttle Columbia (STS 3)	Mar. 22, 1982	Jack R. Lousma C. Gordon Fullerton	8 : 4 : 49	Third flight of Space Shuttle, second scientific payload (OSS 1). Second test of remote manipulator arm. Flight extended 1 day because of flooding at primary landing site; alternate landing site used. Returned for reuse.

U.S. and Soviet Manned Spaceflights 1961–1985

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz T-5	May 13, 1982	Anatoliy Berezovoy Valentin Lebedev	211 : 9 : 5	Docked with Salyut 7. Crew duration of 211 days. Crew returned in Soyuz T-7.
Soyuz T-6	June 24, 1982	Vladimir Dzhanibekov Aleksandr Ivanchenkov Jean-Loup Chretien	7 : 21 : 51	Docked with Salyut 7. Chretien first French cosmonaut to orbit.
Space Shuttle Columbia (STS 4)	June 27, 1982	Thomas K. Mattingly II Henry W. Hartsfield, Jr.	7 : 1 : 9	Fourth flight of Space Shuttle, first DoD payload, additional scientific payloads. Returned July 4. Completed orbital flight testing program. Returned for reuse.
Soyuz T-7	Aug. 19, 1982	Leonid Popov Aleksandr Serebrov Svetlana Savitskaya	7 : 21 : 52	Docked with Salyut 7. Savitskaya second Soviet woman to orbit. Crew returned in Soyuz T-5.
Space Shuttle Columbia (STS 5)	Nov. 11, 1982	Vance D. Brand Robert F. Overmyer Joseph P. Allen William B. Lenoir	5 : 2 : 14	Fifth flight of Space Shuttle, first operational flight; launched 2 commercial satellites (SBS 3 and Anik C-3); first flight with 4 crewmembers. EVA test canceled when spacesuits malfunctioned.
Space Shuttle Challenger (STS 6)	Apr. 4, 1983	Paul J. Weitz Karol J. Bobko Donald H. Peterson Story Musgrave	5 : 0 : 24	Sixth flight of Space Shuttle, launched TDRS 1.
Soyuz T-8	Apr. 20, 1983	Vladimir Titov Gennady Strekalov Aleksander Serebrov	2 : 0 : 18	Failed to achieve docking with Salyut 7 station.
Space Shuttle Challenger (STS 7)	June 18, 1983	Robert L. Crippen Frederick H. Hauck John M. Fabian Sally K. Ride Norman T. Thagard	6 : 2 : 24	Seventh flight of Space Shuttle, launched 2 commercial satellites (Anik C-2 and Palapa B-1), also launched and retrieved SPAS 01; first flight with 5 crewmembers, including first woman U.S. astronaut.
Soyuz T-9	June 28, 1983	Vladimir Lyakhov Aleksandr Aleksandrov	149 : 9 : 46	Docked with Salyut 7 station.
Space Shuttle Challenger (STS 8)	Aug. 30, 1983	Richard H. Truly Daniel C. Brandenstein Dale A. Gardner Guion S. Bluford, Jr. William E. Thornton	6 : 1 : 9	Eighth Flight of Space Shuttle, launched one commercial satellite (Insat 1-B), first flight of U.S. black astronaut
Space Shuttle Columbia (STS 9)	Nov. 28, 1983	John W. Young Brewster W. Shaw Owen K. Garriott Robert A. R. Parker Byron K. Lichtenberg Ulf Merbold	10 : 7 : 47	Ninth flight of Space Shuttle, first flight of Spacelab 1, first flight of 6 crewmembers, one of whom was West German, first non-U.S. astronaut to fly in U.S. space program.
Space Shuttle Challenger (STS-41B)	Feb. 3, 1984	Vance D. Brand Robert L. Gibson Bruce McCandless Ronald E. McNair Robert L. Stewart	7 : 23 : 16	Tenth flight of Space Shuttle, two communication satellites failed to achieve orbit. First use of Manned Maneuvering Unit (MMU) in space.
Soyuz T-10	Feb. 8, 1984	Leonid Kizim Vladimir Solovev Oleg Atkov	62 : 22 : 43	Docked with Salyut 7 station. Crew set space duration record of 237 days. Crew returned in Soyuz T-11.
Soyuz T-11	Apr. 3, 1984	Yuriy Malyshev Gennadiy Strekalov Rakesh Sharma	181 : 21 : 48	Docked with Salyut 7 station. Sharma first Indian in space. Crew returned in Soyuz T-10.
Space Shuttle Challenger (STS-41C)	Apr. 6, 1984	Robert L. Crippen Frances R. Scobee Terry J. Hart George D. Nelson James D. Van Hoften	6 : 23 : 41	Eleventh flight of Space Shuttle, deployment of LDEF-1, for later retrieval, Solar Maximum Satellite retrieved, repaired, and redeployed.
Soyuz T-12	July 17, 1984	Vladmir Dzhanibekov Svetlana Savistskaya Igor Volk	11 : 19 : 14	Docked with Salyut 7 station. First woman extravehicular activity.

U.S. and Soviet Manned Spaceflights 1961-1985

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Space Shuttle Discovery (STS-41D)	Aug, 30, 1984	Henry W. Hartsfield Michael L. Coats Richard M. Mullane Steven A. Hawley Judith A. Resnick Charles D. Walker	6 : : 56	Twelfth flight of Space Shuttle. First flight of U.S. non-astronaut.
Space Shuttle Challenger (STS-41G)	Sept. 5, 1984	Robert L. Crippen Jon A. McBride Kathryn D. Sullivan Sally K. Ride David Leestma Paul D. Scully-Power Marc Garneau	8 : 5 : 24	Thirteenth flight of Space Shuttle, first flight of 7 crewmembers, including first flight of two U.S. women and one Canadian.
Space Shuttle Discovery (STS-51A)	Nov. 8, 1984	Frederick H. Hauck David M. Walker Joseph P. Allen Anna L. Fisher Dale A. Gardner	7 : 23 : 45	Fourteenth flight of Space Shuttle, first retrieval and return of two disabled communications satellites (Westar 6, Palapa B2) to Earth.
Space Shuttle Discovery (STS-51C)	Jan. 24, 1985	Thomas K. Mattingly Loren J. Shriver Ellison S. Onizuka James F. Buchli Gary E. Payton	3 : 1 : 33	Fifteenth STS flight. Dedicated DoD mission.
Space Shuttle Discovery (STS-51D)	Apr. 12, 1985	Karol J. Bobko Donald E. Williams M. Rhea Seddon S. David Griggs Jeffrey A. Hoffman Charles D. Walker E. J. "Jake" Garn	6 : 23 : 55	Sixteenth STS flight. Two communications satellites. First U.S. Senator in space.
Space Shuttle Challenger (STS-51B)	Apr. 29, 1985	Robert F. Overmyer Frederick D. Gregory Don L. Lind Norman E. Thagard William E. Thornton Lodewijk Vandenberg Taylor Wang	7 : : 9	Seventeenth STS flight. Spacelab-3 in cargo bay of shuttle.
Soyuz T-13	June 5, 1985	Vladimir Dzhanibekov Viktor Savinykh	112 : 3 : 12	Repair of Salyut-7. Dzhanibekov returned to earth with Grechko on Soyuz T-13 spacecraft, Sept. 26, 1985.
Space Shuttle Discovery (STS-51G)	June 17, 1985	Daniel C. Brandenstein John O. Creighton Shannon W. Lucid John M. Fabian Steven R. Nagel Patrick Baudry Sultan bin Salman bin Abdul-Aziz Al-Saud	7 : 1 : 39	Eighteenth STS flight. Three communications satellites. One reusable payload-Spartan-1. First U.S. flight with French and Saudi Arabian crewmen.
Space Shuttle Challenger (STS-51F)	July 29, 1985	Charles G. Fullerton Roy D. Bridges Karl C. Henize Anthony W. England F. Story Musgrave Loren W. Acton John-David F. Bartow	7 : 22 : 45	Nineteenth STS flight. Spacelab-2 in cargo bay.
Space Shuttle Discovery (STS-51I)	Aug. 27, 1985	Joe H. Engle Richard O. Covey James D. van Hoften William F. Fisher John M. Lounge	7 : 2 : 18	Twentieth STS flight. Launched three communications satellites. Repaired Syncom IV-3.
Soyuz T-14	Sep. 17, 1985	Vladimir Vasyutin Georgiy Grehko Aleksandr Volkov	64 : 21 : 52	Docked with Salyut-7 station. Viktor Savinykh, Aleksandr Volkov and Vladimir Vasyutin returned to Earth Nov. 21, 1985 when Vasyutin became ill.

U.S. and Soviet Manned Spaceflights 1961-1985

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Space Shuttle Atlantis (STS-51J)	Oct. 3, 1985	Karol J. Bobko Ronald J. Grabe Robert A. Stewart David C. Hilmers William A. Pailes	4 : 1 : 45	Twenty-first STS flight. Dedicated DoD mission.
Space Shuttle Challenger (STS-61A)	Oct. 30, 1985	Henry W. Hartsfield Steven R. Nagel Bonnie J. Dunbar James F. Buchli Guion S. Bluford Ernst Messerschmid Reinhard Furrer Wubbo J. Ockels	7 : : 45	Twenty-second STS flight. Dedicated German Spacelab D-1 in shuttle cargo bay.
Space Shuttle Atlantis (STS-61B)	Nov. 27, 1985	Brewster H. Shaw Bryan D. O'Connor Mary L. Cleve Sherwood C. Spring Jerry L. Ross Rudolfo Neri Vela Charles D. Walker	6 : 22 : 54	Twenty-third STS flight. Launched three communications satellites. First flight of Mexican astronaut.

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant[a]	Thrust (kilo-newtons)	Max. Dia. × Height (m)	Max. Payload (kg)[b] 185-Km Orbit	Geosynch.-Transfer Orbit	Circular Sun-Synch. Orbit	First Launch[c]
Scout	1. Algol IIIA	Solid	431.1	1.14×22.9	255	–	155[d]	1979(60)
	2. Castor IIA	Solid	285.2		205[d]			
	3. Antares IIIA	Solid	83.1					
	4. Altair IIIA	Solid	25.6					
Delta 2900 Series (Thor-Delta)	1. Thor plus	LOX/RP-1	912.0	2.44×35.4	2,000	705	1,250[d]	1973(60)
	9 TX 354-5	Solid	147 each		1,410[d]			
	2. Delta	N_2O_4/Aerozine-50	44.2					
	3. TE 364-4	Solid	65.8					
Delta 3900 Series (Thor-Delta)[e]	1. Thor plus	LOX/RP-1	912.0	2.44×35.4	3,045	1,275	2,135[d]	1982(60)
	9 TX 526-2	Solid	375 each		2,180[d]			
	2. Delta	N_2O_4/Aerozine-50	44.2					
Atlas E	1. Atlas booster & sustainer	LOX/RP-1	1,722.0	3.05×28.1	2,090[d f]	–	1,500[d]	1972(67)
Atlas-Centaur	1. Atlas booster & sustainer	LOX/RP-1	1,913.0	3.05×45.0	6,100	2,360	–	1984(62)
	2. Centaur	LOX/LH_2	146.0					
					185-Km Orbit	Direct Geo-synch. Orbit	Sun-Synch. Transfer Orbit	
Titan IIIB-Agena	1. LR-87	N_2O_4/Aerozine	2,341.0	3.05×48.4	3,600[d]	–	3,060[d]	1966
	2. LR-91	N_2O_4/Aerozine	455.1					
	3. Agena	IRFNA/UDMH	71.2					
Titan III(34)D/IUS	1. Two 5½-segment, 3.05 m dia	Solid	11,564.8	3.05×48.0	14,920	1,850[d]	–	1982
	2. LR-87	N_2O_4/Aerozine	2,366.3					
	3. LR-91	N_2O_4/Aerozine	449.3					
	4. IUS 1st stage	Solid	275.8					
	5. IUS 2nd stage	Solid	115.7					
Titan III(34)D/Transtage	Same as Titan III(34)D plus:			3.05×46.9	14,920	1,855[d]	–	1984[h]
	4. Transtage	N_2O_4/Aerozine	69.8					
					280- to 420-Km Orbit			
Space Shuttle (reusable)	1. Orbiter; 3 main engines (SSMEs) fire in parallel with SRBs	LOX/LH_2	1,670 each	23.79×37.24 wing span long	29,500 in full performance configuration			1981
	2. Two-solid-fueled rocket boosters (SRBs) fire in parallel with SSMEs	AL/NH_4CLO_4/PBAN	11,790 each	3.71×45.45				
	Mounted on external tank (ET)			8.40×46.88				

[a] 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/N_2H_4 = N_2O_4/aerozine; liquid oxygen and liquid hydrogen = LOX/LH_2; aluminum, ammonium perchlorate, and polybutadiene acrolonitrile terpolymer = AL/NH_4CLO_4/PBAN.

[b] Due east launch except as indicated.

[c] The date of first launch applies to this latest modification with a date in parentheses for the initial version.

[d] Polar launch.

[e] Maximum performance based on 3920, 3920/PAM configurations. PAM = payload assist module (a private venture).

[f] With dual TE 364-4.

[g] With 96° flight azimuth.

[h] Initial operational capability in December 1982; launch to be scheduled as needed.

NOTE: Data should not be used for detailed NASA mission planning without concurrence of the director of Space Transportation System Support Programs.

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY – BUDGET AUTHORITY

(in millions of dollars)

Fiscal Year	NASA		Defense	Energy	Commerce	Interior	Agriculture	NSF	Total Space
	Total	Space[a]							
1959	330.9	260.9	489.5	34.3	...	...	...	...	784.7
1960	523.6	461.5	560.9	43.3	...	...	...	0.1	1,065.8
1961	964.0	926.0	813.9	67.7	...	...	...	.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7	...	...	1.3	3,294.8
1963	3,673.0	3,626.0	1,549.9	213.9	43.2	...	...	1.5	5,434.5
1964	5,099.7	5,016.3	1,599.3	210.0	2.8	...	...	3.0	6,831.4
1965	5,249.7	5,137.6	1,573.9	228.6	12.2	...	...	3.2	6,955.5
1966	5,174.9	5,064.5	1,688.8	186.8	26.5	...	...	3.2	6,969.8
1967	4,965.6	4,830.2	1,663.6	183.6	29.3	...	...	2.8	6,709.5
1968	4,587.3	4,430.0	1,921.8	145.1	28.1	02	0.5	3.2	6,528.9
1969	3,990.9	3,822.0	2,013.0	118.0	20.0	.2	.7	1.9	5,975.8
1970	3,745.8	3,547.0	1,678.4	102.8	8.0	1.1	.8	2.4	5,340.5
1971	3,311.2	3,101.3	1,512.3	94.8	27.4	1.9	.8	2.4	4,740.9
1972	3,306.6	3,071.0	1,407.0	55.2	31.3	5.8	1.6	2.8	4,574.7
1973	3,406.2	3,093.2	1,623.0	54.2	39.7	10.3	1.9	2.6	4,824.9
1974	3,036.9	2,758.5	1,766.0	41.7	60.2	9.0	3.1	1.8	4,640.3
1975	3,229.1	2,915.3	1,892.4	29.6	64.4	8.3	2.3	2.0	4,914.3
1976	3,550.3	3,225.4	1,983.3	23.3	71.5	10.4	3.6	2.4	5,319.9
Transitional Quarter	931.8	849.2	460.4	4.6	22.2	2.6	.9	.6	1,340.5
1977	3,817.8	3,440.2	2,411.9	21.7	90.8	9.5	6.3	2.4	5,982.8
1978	4,060.1	3,622.9	2,738.3	34.4	102.8	9.7	7.7	2.4	6,518.2
1979	4,595.5	4,030.4	3,035.6	58.6	98.4	9.9	8.2	2.4	7,243.5
1980	5,240.2	4,680.4	3,848.4	39.6	92.6	11.7	13.7	2.4	8,688.8
1981	5,518.4	4,992.4	4,827.7	40.5	87.0	12.3	15.5	2.4	9,977.8
1982	6,043.9[b]	5,527.6	6,678.7	60.6	144.5	12.1	15.2	2.0	12,440.7
1983	6,875.3[c]	6,327.9	9,018.9	38.9	177.8	4.6	20.4	0.0[d]	15,588.5
1984	7,248.0	6,648.3	10,194.9	34.1	236.0	3.0	19.4	0.0	17,135.7
1985	7,572.6	6,924.9	12,767.9	34.0	422.9	2.0	14.8	0.0	20,166.5
1986 est.	7,~~306~~.4	~~6,700.5~~ 7,165.0	14,126.0	36.4	320.6	2.0	14.7	0.0	21,200.5
1987 est.	~~7,694.4~~ 10,507.0	6,988.3 9,809.0	~~16,286.8~~ 15,717.0	89.1	248.9	2.0	15.3	0.0	23,630.4

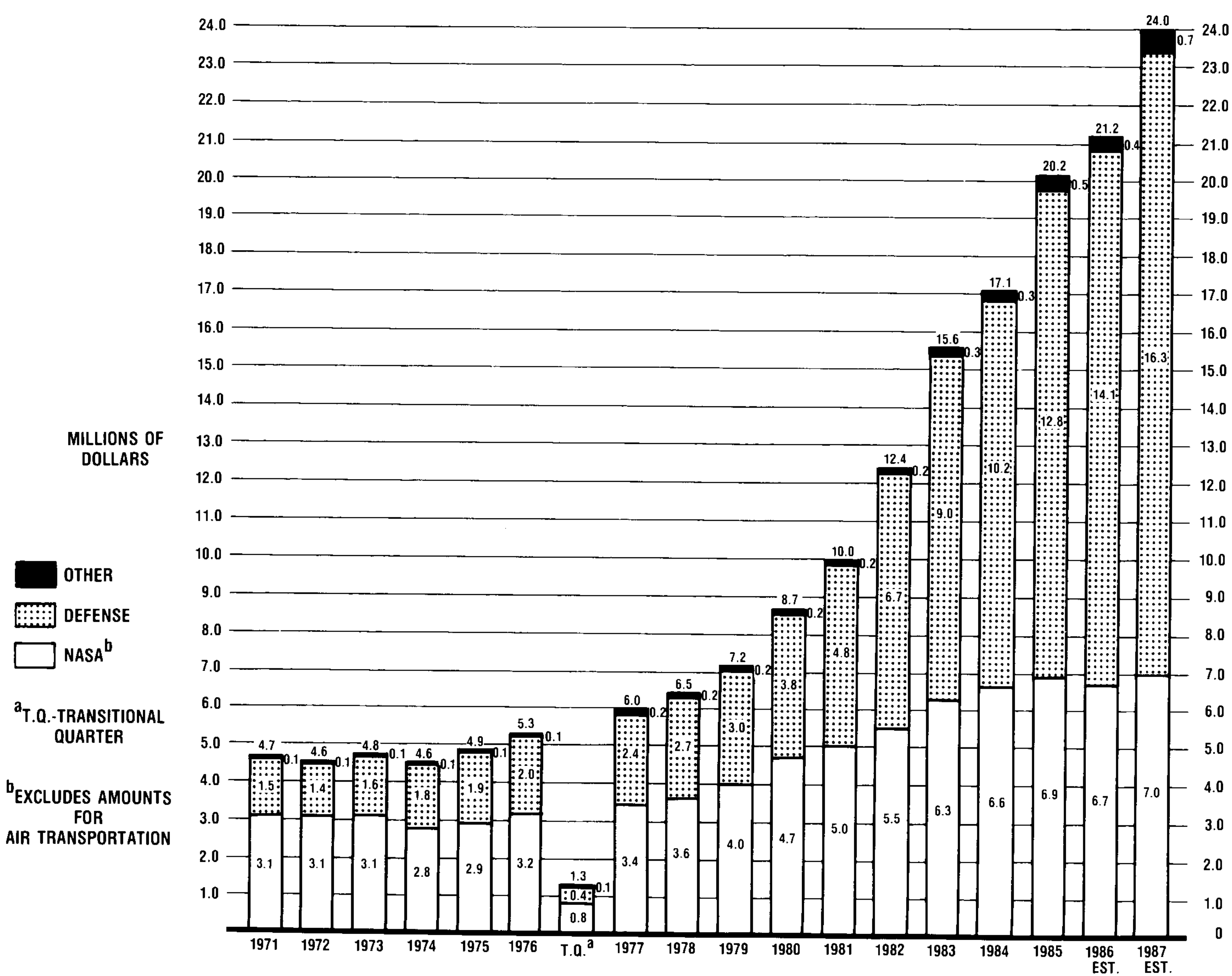
[a] Excludes amounts for air transportation (subfunction 402).
[b] Includes $33.5 million unobligated funds that lapsed.
[c] Includes $37.6 million for reappropriation of prior year funds.
[d] NSF funding of balloon research transferred to NASA.

SOURCE: Office of Management and Budget.

88 est 9,481.0 8,756.0 17,196.0

U.S. Space Budget—Budget Authority FY 1971-1985

(may not add because of rounding)



SOURCE: OFFICE OF MANAGEMENT AND BUDGET

APPENDIX E-2

Space Activities Budget

(in millions of dollars by fiscal year)

Federal Space Programs	Budget Authority 1985 Actual	Budget Authority 1986 Estimate	Budget Authority 1987 Estimate	Budget Outlays 1985 Actual	Budget Outlays 1986 Estimate	Budget Outlays 1987 Estimate
Federal agencies:						
NASA[a]	6,924.9	6,700.5	6,988.3	6,607.4	6,732.0	6,826.2
Defense	12,767.9	14,126.3	16,286.8	10,441.3	11,850.4	13,973.4
Energy	34.0	36.4	89.1	34.0	36.4	89.1
Commerce	422.9	320.6	248.9	155.4	505.3	278.2
Interior	2.0	2.0	2.0	2.0	2.0	2.0
NSF[b]	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	14.8	14.7	15.3	14.7	14.7	15.3
Total	20,166.5	21,200.5	23,630.4	17,254.8	19,140.8	21,184.2
NASA:						
Space flight	3,951.5	3,775.8	3,777.4	3,988.6	3,809.4	3,760.9
Space science, applications, and technology	2,023.0	2,091.9	2,218.7	1,857.9	2,087.6	2,160.8
Air transportation	647.7	605.9	706.1	643.2	608.9	651.6
Supporting operations	950.4	832.8	992.2	760.9	835.0	904.5
Total NASA	7,572.6	7,306.4	7,694.4	7,250.6	7,340.9	7,477.8

[a] Excludes amounts for air transportation. Includes $37.6 million for reappropriation of prior year funds.
[b] NSF funding for balloon research transferred to NASA.

SOURCE: Office of Management and Budget.

APPENDIX E-3

Aeronautics Budget

(in millions of dollars by fiscal year)

Federal Aeronautics Programs	Budget Authority 1985 Actual	Budget Authority 1986 Estimate	Budget Authority 1987 Estimate	Budget Outlays 1985 Actual	Budget Outlays 1986 Estimate	Budget Outlays 1987 Estimate
NASA[a]	647.7	605.9	706.1	643.2	608.9	651.6
Department of Defense[b]	3,442.0	4,124.9	4,557.0	3,101.1	3,411.8	3,812.4
Department of Transportation[c]	265.0	181.8	134.5	265.5	262.6	177.7
Total	4,354.7	4,912.6	5,397.6	4,009.8	4,283.3	4,641.7

[a] Research and Development, Construction of Facilities, Research and Program Management.
[b] Research, Development, Testing, and Evaluation of aircraft and related equipment.
[c] Federal Aviation Administration: Research, Engineering, and Development; Facilities, Engineering, and Development.

SOURCE: Office of Management and Budget.

Information: To obtain general information about the contents of this report, contact S.E. Kale, Code LB, NASA Headquarters, Washington, D.C. 20546, (202) 453-8337.

U. S. GOVERNMENT PRINTING OFFICE : 1986 O - 169-254