Aeronautics and Space Report of the President

1982 Activities

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Aeronautics and Space Report of the President

1982 Activities

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

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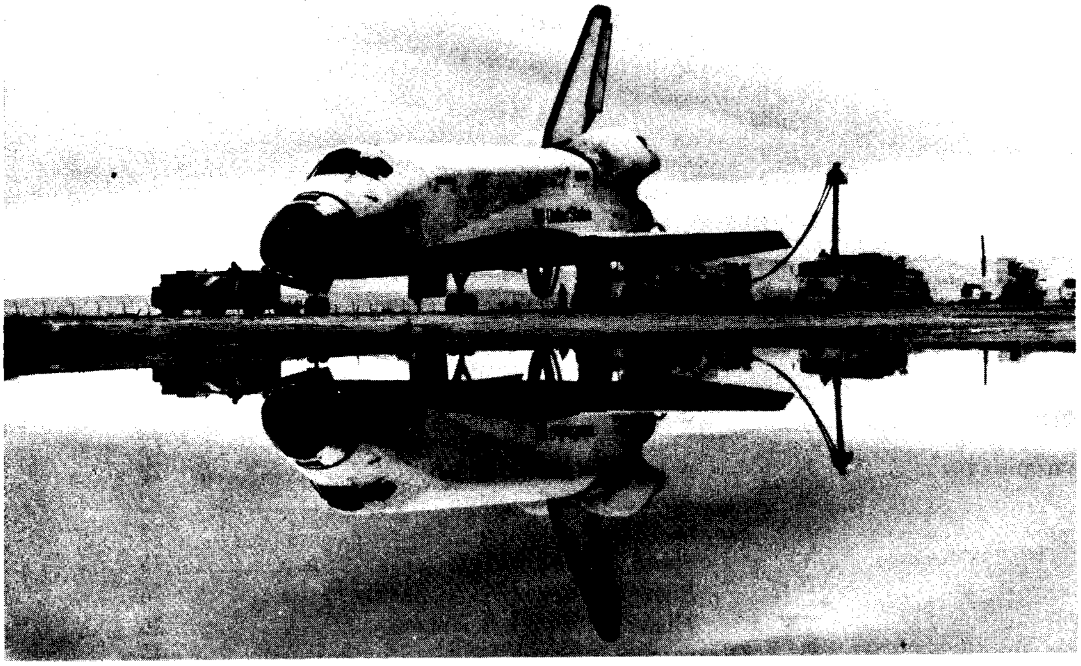
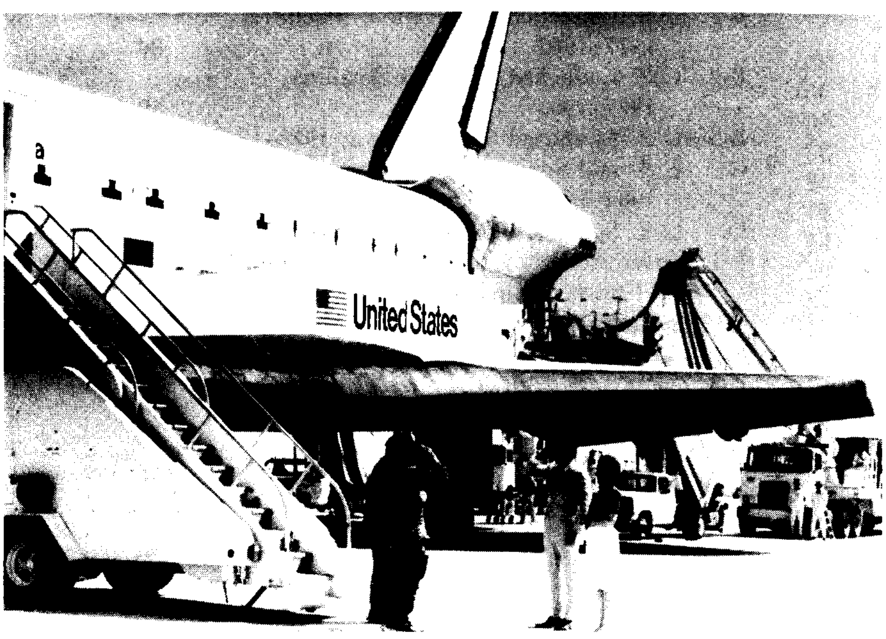
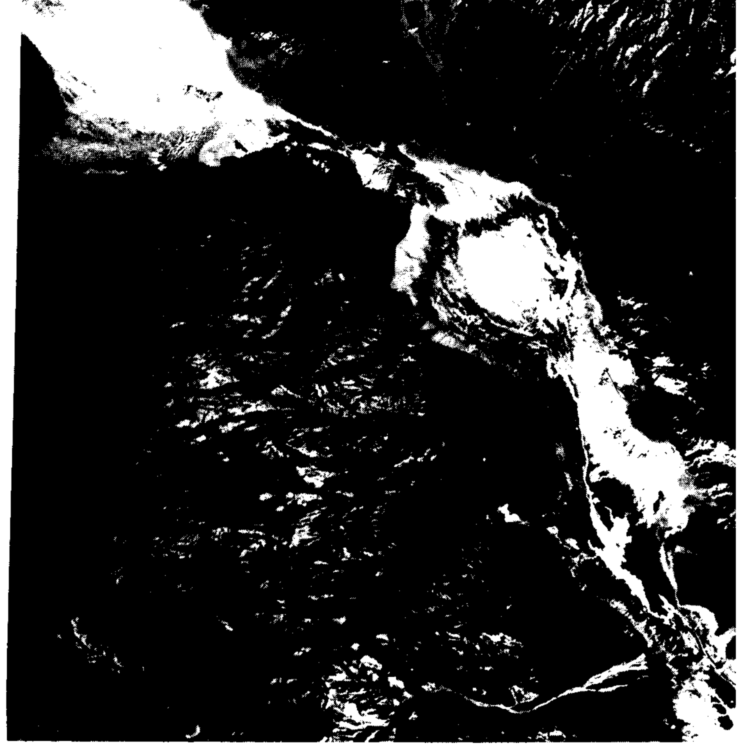


Aerospace Events of 1982

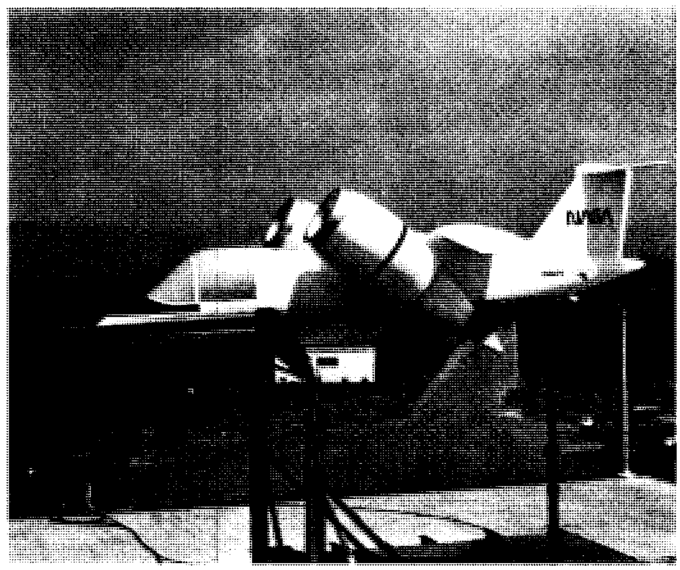
Postlanding processing begins on Space Shuttle *Columbia* (above) after touchdown 16 November at Dryden Flight Research Facility, California, to complete the first operational mission (flight STS 5) of the Space Transportation System. Uncommon rainwater has turned the usually dry lake bed into a mirror. During STS 5, the Satellite Business System's *SBS 3* communications satellite (at left) was spun out of *Columbia*'s cargo bay 11 November in the first satellite launch from the Shuttle. Beyond the open *SBS 3* cradle, Telesat Canada's still-enclosed *Anik C-3* awaits launch into its orbit the next day.

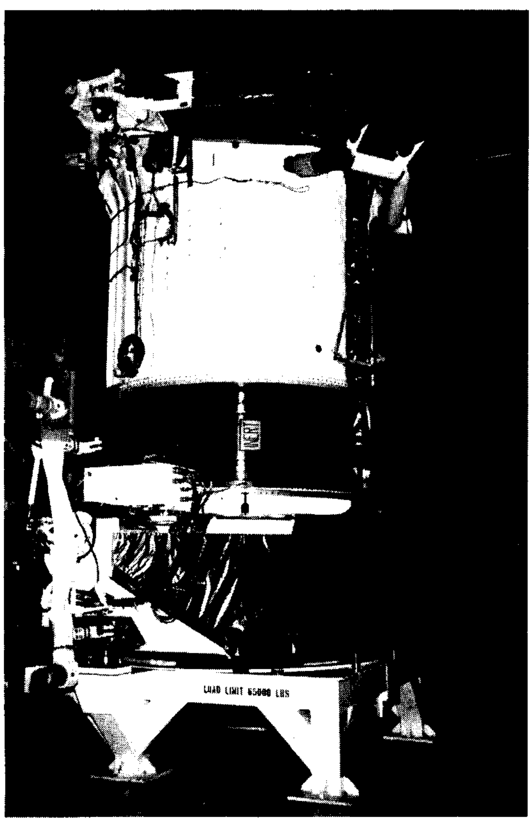


President and Mrs. Reagan greet astronauts Ken Mattingly (left) and Henry Hartsfield on *Columbia*'s 4 July landing after the STS 4 test mission. The first four orbital test flights proved the Space Transportation System was ready for operations.



Orbiting satellites continue to monitor the earth: A 40-km-wide area (at right) of the Death Valley region of California and Nevada was imaged by *Landsat 4*'s new thematic mapper on 17 November, showing vegetation-sparse terrain, snow, rock types, geological structures, and mineralization in detail. A *GOES 4* weather satellite photo (above) taken on 23 November shows Hurricane Iwa 240 km southwest of Kauai, Hawaii, accelerating rapidly northeastward. Iwa passed Kauai a few hours later, with winds in excess of 160 km per hour.





The Air Force's inertial upper stage (IUS) "pathfinder" test vehicle (at left) is mounted in the Shuttle support cradle. An expendable upper stage, the IUS will transfer payloads from the Shuttle's low earth orbit to higher mission orbits. As an upper stage on the Titan launch vehicle in 1982, it placed two DSCS communications satellites in orbit for the Department of Defense. Above, stand tests of a large-scale model at Ames Research Center investigate characteristics of a turbofan-powered, subsonic V/STOL concept in a joint Navy–NASA–Grumman Aerospace research program.

Summary

Three orbital flights of the Space Shuttle *Columbia* in 1982 lifted the U.S. space program's reusable Space Transportation System from flight testing into operations. The five-day STS 5 flight in November—manned by four astronauts for the first time and following the eight-day STS 3 and seven-day STS 4—delivered two commercial satellites to orbit on the Shuttle's first operational mission, promising returns on the nation's investment in flexible, routine, round-trip access to space.

Other orbiting spacecraft sharpened our observation of the earth, expanded the increasingly important civilian and military communications and weather networks, and advanced our knowledge of the atmosphere, the interstellar medium, and the sun's effects on the earth. A new thematic mapper on *Landsat 4*, launched into orbit by a Delta launch vehicle in July, began producing data of even higher quality than expected, for geophysical sciences, mapping, and monitoring the earth's resources.

The year's 18 U.S. space launches included the 3 launches of the reusable Space Shuttle and 15 of expendable vehicles, 9 of them by NASA and 6 by the Department of Defense (DoD). Because DoD launched two satellites on one vehicle, total payloads placed in orbit by expendable vehicles reached 16. The 3 Shuttle flights, plus the 2 satellites placed in separate orbits from one of those flights, added 5 payloads to the count, for a total of 21 U.S. payloads launched into orbit during 1982. Among these, NASA launched 10 communications satellites—all reimbursable launches for private or international users—and 1 earth resources satellite, *Landsat 4*, to be turned over to the National Oceanic and Atmospheric Administration (NOAA) in 1983. DoD launched 2 communications satellites, 1 weather satellite, and 4 other military satellites. Shuttle flights also carried experiments into orbit and back to earth for atmospheric and earth observations, materials processing, life sciences, and a DoD mission.

On 4 July, the day *Columbia* landed after its fourth flight—its second 1982 mission—President Reagan issued a statement on United States space policy for the next decade (see appendix F). The president reaffirmed the national commitment to exploration and use of space for the national well-being and "by all nations for peaceful purposes and the benefit of mankind." He declared the United States was committed to maintaining world leadership in space transportation, space science, applications, and technology. Among objectives was exploration of needs and concepts for permanent space facilities. The president also reaffirmed the principle of two separate, interacting, civil and military U.S. space programs. He stated the basic goals of U.S. space policy are to:

- strengthen the security of the United States;
- maintain United States space leadership;
- obtain economic and scientific benefits through the exploitation of space;
- expand United States private-sector investment and space-related activities;
- promote international cooperative activities in the national interest; and
- cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

In aeronautics, NASA completed two large wind-tunnel test facilities. DoD and NASA projects made advances in testing new aircraft wing designs, fuel-efficient engines, composite structures, digital fly-by-wire controls, vertical or short takeoff and landing aircraft, supersonic technology, and rotorcraft. DoD awarded development contracts for the modernized multirole B-1B bomber and began studies for an advanced tactical fighter for the 1990s. NASA and the Federal Aviation Administration (FAA) experimented with new technology and materials to reduce hazards to aircraft from lightning, wind shear, fire, and icing.

In November, the president's Office of Science and Technology Policy issued an aeronautical policy statement recognizing that a strong aeronautical industry is essential to the nation's security and economy and that the federal government's role in providing basic technology is important to the nation's leadership in aviation (the findings and recommendations are reproduced in appendix G).

UNISPACE '82, the second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, held in Vienna in August, emphasized international cooperation and further extension of space science and technology to developing countries. The United States proposed a number of initiatives, including U.S.-sponsored conferences on global disaster monitoring and early warning and on rural satellite communications.

Communications

Communications satellites again dominated U.S. launch numbers in 1982, accounting for 12 of the 21 payloads orbited during the year. NASA launched 5 for the ever-growing U.S. domestic industry, using both expendable launch vehicles and the reusable Shuttle. It launched 1 for India, 2 for Canada, and 2 for the International Telecommunications Satellite Organization (INTELSAT). DoD launched 2 satellites for communications support to worldwide military forces. Both NASA and DoD programs emphasized new technology, with NASA research refocusing on high-risk technology to maintain U.S. preeminence in the field. U.S. industry continued as the dominant supplier of communications satellites for the world community.

Operational Space Systems

INTELSAT. Annual growth rate of INTELSAT revenues and circuit use continued at more than 24 percent during 1982. The fourth and fifth of the Intelsat V series of satellites were launched into orbit in March and September, upgrading the global network, and the sixth was scheduled for early 1983 launch, with up to four more to follow. INTELSAT placed orders for six Intelsat V-A spacecraft for 1984 and 1985 launch, each to provide some 25 percent greater capacity than that of the Intelsav V. It awarded a contract for the design and construction of the next-generation Intelsat VI series, which will be compatible with Space Shuttle launch.

Domestic Communications Satellites. The launch of five commercial domestic satellites expanded the U.S. communications network, and at the end of the year domestic satellites served the nation from 15 locations. New technology increased economic benefits and improved service. The Federal Communications Commission prepared to release a plan at the beginning of 1983 for reduced orbital spacing to accommodate the increasing number of domestic satellites through the 1980s. The FCC also issued permits for construction of direct-broadcast satellites offering direct-to-home television service.

Military Communications Satellites. DoD began major improvements in the operational Defense Satellite Communications System (DSCS) for command and support forces with the launch of the first DSCS III satellite in October. The dual launch also put a DSCS II satellite into orbit. The new DSCS III system includes antijamming and other protection. Four FLTSATCOM satellites continued worldwide service for tactical-peacetime and mixed-management needs of the Navy and unified and specified commands, as well as for the strategic forces. Three additional satellites are planned. Fabrication of the Navy's leased satellite (LEASAT) progressed toward scheduled 1984 Space Shuttle launch.

INMARSAT. The International Maritime Satellite Organization in February 1982 began operations in the maritime-mobile satellite service, using capacity that includes the Marisat satellites. Communications Satellite Corporation is the U.S. signatory in INMARSAT. At the end of 1982, the global system served 1309 ship and 38 land stations, including 292 U.S. ship and 17 U.S. land stations. Ship stations were increasing at a rate of nearly five percent a month.

Military Navigation Satellites. Congress approved, and the Air Force began, multiyear procurement of 28 satellites for the joint-service Navstar Global Positioning System (GPS), which will improve weapon delivery, worldwide rapid-deployment, and reconnaissance capabilities. With a developmental system of five Navstar satellites already in use, an 18-satellite operational system is to be deployed by late 1988, providing accurate positioning and velocity data and accurate time synchronization. Contractors delivered models of GPS user equipment in November for field testing, and North Atlantic Treaty Organization nations began demonstrations using GPS.

Space Communications Experiments

Experimental Satellites. NOAA-E, first of NOAA's Advanced Tiros N environmental satellites (to be named *NOAA 8* when launched into orbit in early 1983), will carry instruments to participate with the Soviet *COSPAS 1* (launched in June 1982) in a 15-month evaluation of the international COSPAS-SARSAT satellite search and rescue project. The project already has assisted in a number of accidents by pinpointing positions of ships and aircraft in distress.

NOAA's National Marine Fisheries Service (NMFS) completed a successful demonstration of satellite communications in the Gulf of Mexico. Information on fish and shrimp was transmitted through NASA's *ATS 3* satellite and the ARGOS data collection system on NOAA's polar-orbiting satellites, speeding information to users.

Communications Research. NASA's restructured communications program concentrated on advanced technology usable in multiple-frequency bands and in a wide range of future systems, such as the Advanced Communications Technology Satellite (*ACTS*) to test high-gain multibeam antennas in orbit. DoD concept validation studies concluded in September 1982 with a request for proposals for engineering development of the MILSTAR satellite, to operate in the 44- and 20-GHz bands for worldwide, jam-resistant communications for all the military services. A Defense Advanced Research Project Agency (DARPA) and Navy program continued to develop technology for laser communications from space to submarines, beginning spacecraft design and laser spaceworthiness engineering for Submarine Laser Communications Satellites (SLCSATs).

Earth's Resources and Environment

New sensors on Space Shuttle and satellites returned increasingly refined data on the earth's surface, resources, weather, and atmospheric composition, as applications of this information for man's use continued in 1982.

Inventorying and Monitoring

Analyses found that the Shuttle's first scientific payload, OSTA 1 on the November 1981 flight, obtained remote-sensing data contributing to the study of continental geology, atmospheric chemistry, oceanography, meteorology, and marine biology. The imaging radar-A (SIR-A) obtained clear images of the earth's surface through clouds and darkness and even, in some very dry areas, of features beneath the surface.

Landsat 4, launched 16 July 1982 to replace *Landsat 3* in monitoring the earth's resources and environment, introduced new technology for remote sensing with its thematic mapper. The experimental sensor has sent back images exceeding expectations, promising greatly improved information for such users as farmers, urban planners, foresters, and oil companies. NOAA prepared to take over operational responsibility for the Landsat program in January 1983. Cooperative projects with private industry meanwhile continued to validate the usefulness of remote sensing for resource management, and sales of remotely sensed data in 1982 totaled $4.6 million, almost $2 million from the Landsat program.

AgRISTARS, the multiagency Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing, was reduced in scope, focusing on Department of Agriculture's priority needs. The department will continue the program through 1986, to use and assess data from *Landsat 4*'s thematic mapper. First analysis verified greatly improved agricultural information from the mapper. NASA will phase out its participation in the program by 1984.

The Navy began the Geodetic/Geophysical Satellite program in 1982, planning a 1984 launch of *Geosat* to improve accuracy of the marine geoid and to detect hazards to underwater navigation.

Environmental Analysis and Protection

Weather Satellite Operations. During 1982, NOAA's two polar-orbiting satellites, *NOAA 6* and *7* (launched in 1979 and 1981), and two geostationary satellites, *GOES 4* and *5* (launched in 1980 and 1981), provided continuous data for national and international weather prediction and warning. Customers for Department of Commerce weather services increased, and weather broadcasts expanded. The new weather satellite NOAA-E (*NOAA 8*) will have enlarged payload capability for environmental monitoring, as well as search and rescue instruments, when launched in 1983.

An operational demonstration program assessing the visible-infrared, spin-scan radiometer (VISSR), atmospheric sounder (VAS) on *GOES 4* and *5* continued into November, imaging the entire earth's surface and cloud cover and measuring atmospheric temperature and moisture. Water-vapor images already have revealed atmospheric circulation patterns valuable for weather detection and forecasting over oceans and other areas with sparse conventional weather data. VAS data have been immediately useful for maritime and aviation support. The VAS on *GOES 4* failed in November, but the program was to resume after launch of GOES-F in 1983.

DoD's Defense Meteorological Satellite Program (DMSP) also continued. Data, merged with Department of Commerce satellite data for weather forecasts and warnings, supported U.S. military services around the world.

Atmospheric Research. *SME*, NASA's Solar Mesosphere Explorer launched in 1981, supplied data during 1982 that gave insights into the physical and chemical processes of the earth's stratosphere and mesosphere and the results affecting man. A November 1982 Space Shuttle experiment made the first global measurements of carbon monoxide distribution in the atmosphere. Cooperative NASA and Environmental Protection Agency studies made progress in investigations of air pollution causes, duration, effects, and relation to meteorological conditions and also examined movement of ozone into the troposphere.

NOAA's Space Environmental Service Center provided warnings and forecasts for Space Shuttle missions, with specific support to solar payloads, including an experiment observing polarized hard x-ray emission from solar flares. It also provided radiation forecasts for launch and in-orbit operation, including crew protection.

Materials Processing

Among several materials processing experiments flown on the Space Shuttle during the year, a commercially funded apparatus on the fourth STS mission used the low gravity of space to improve separation of biological materials. It produced 460 times as much of the experiment material as can be produced on the earth, with 5 times the purity.

Space Science

Space science programs use satellites and space probes, Space Shuttle missions, suborbital vehicles, and ground faciliites to investigate the origin and evolution of life, the earth, the solar system, and the universe. They also take advantage of the space environment to study medicine and biology.

Sun-Earth Studies

Eight Explorer satellites launched from 1973 through 1981—including *DE 1* and *2* Dynamics Explorers launched last year—continued studying solar interactions with the earth's atmosphere and magnetic field. *DE 1* furnished spectacular images of the entire auroral oval while *DE 2* provided correlating measurements of particles and fields, for studying the generation of auroras and influx of energy from high altitudes. Plans proceeded well for cooperative projects on the European International Solar Polar Mission (*ISPM*) to study the sun in 1986.

Study of the Planets.

Five spacecraft launched into deep space during the past 10 years—*Pioneer 10* and *11, Pioneer-Venus 1* orbiter, and *Voyager 1* and *2*—continued to follow their first dramatic discoveries about Jupiter, Saturn, and Venus by returning data on interplanetary space. *Voyager 2*, which transmitted quantities of valuable data and images from its Saturn flyby in 1981, is due to meet Uranus in 1986 and Neptune in 1989, while *Voyager 1* flies out toward the heliospheric boundary. Plans proceeded for 1986 launch of the *Galileo* mission in cooperation with Germany, to reach Jupiter in 1988.

Study of the Universe.

Manufacturing, assembly, and testing began on the *Space Telescope*, scheduled to become—in the mid-1980s—our first major observatory in orbit. A cooperative project with the European Space Agency, it will image astronomical bodies with at least 10 times finer resolution than is possible through the earth's atmosphere, perhaps changing our understanding of the universe.

Analyses of data received 1978–1981 from the *HEAO 2* and *3* High Energy Astronomy Observatories added to knowledge of supernova remnants and the nature of the interstellar medium. Smithsonian Institution scientists studying *HEAO 2* findings discovered a new class of x-ray galaxies, developed a classification scheme for galaxies based on x-ray emission, and found evidence for evolution of the luminosity of quasi-stellar objects. They also found a rapidly blinking x-ray pulsar in a supernova remnant that supports the theory that massive explosions of stars leave behind compact cores of the original stars. The Gamma Ray Observatory (*GRO*), planned for 1988 launch, will extend the study of supernova remnants, observe the center of our galaxy, and make nuclear-chemistry studies of astrophysical objects and the origins of gamma-ray bursts.

Preparations went ahead for a mission to repair the Solar Maximum Mission (*SMM*) in orbit by using a manned maneuvering unit and the Shuttle's remote manipulator system to capture the satellite and redeploy it after exchanging a module. Three *SMM* instruments that continued to operate returned evidences of changes in the heat output of the sun, coinciding with the closing of the period of peak solar activity, and also detected new nuclear reactions in solar flares. The Explorer-class Infrared Astronomy Satellite (*IRAS*), to be launched early in 1983, will survey the whole sky to identify celestial sources of infrared emissions. Development began on the Cosmic Background Explorer (*COBE*), to be launched in 1989 to study diffuse background radiation in the universe.

Life Sciences

Integration of subsystems was in process for a fall 1983 Shuttle launch of the first Spacelab, a multidisciplinary mission. Spacelab 1 will measure coarse radiation inside the Shuttle-borne laboratory, study adaptation of plants and the human body to weightlessness, and examine effects of weightlessness on red blood cells and on the body's immunity to disease. The European Space Agency, which developed Spacelab, is also sponsoring six life sciences experiments on SL 1.

Plant experiments on the third Shuttle mission, as well as research on the ground, contributed to plant science and future cultivation of plants in space. Plants grown in the mini-greenhouse on STS 3 showed a number of changes, including serious chromosome damage. Research into biochemical mechanisms are shedding light on the responses to gravity.

Spacelab 2 and 3, planned for 1984, will test research facilities for carrying plants and animals on the fourth Spacelab mission, in 1985, which will include some 25 life science experiments. The United States will participate in a German mission, Spacelab D-1, scheduled for 1985 to continue research in space motion sickness, and will take part in the Soviet Union's 1983 biological satellite mission, which will fly rats and two monkeys in space for a week. NASA was also accelerating research in new technology and procedures to assist in human adaptation to spaceflight.

Research from the Ground.

Astronomers making observations from the ground, sponsored by the National Science Foundation, found a pulsating white dwarf star, advanced ability to probe the interiors of white dwarfs, studied the center of our own Milky Way galaxy, and recorded the first evidence that the sun's magnetic field partially controls the energy flow over the sun's entire surface. In programs of other agencies, sounding rocket and balloon observations contributed to studies of the stars, the earth's atmosphere, and the sun's corona and its effects on the earth.

Space Transportation

The United States conducts extensive research and development for new space transportation systems and for improving operation, economy, and versatility of existing systems.

Space Transportation System (STS)

The Space Transportation System began operational flights in 1982, after completing the last flights of the four-flight orbital test program. Test flights had demonstrated the Space Shuttle could provide the nation flexible, efficient transportation into space and back for people, equipment, scientific experiments, and commercial and military payloads.

Space Shuttle. The Shuttle orbiter flew three orbital missions during the year—two test missions and the first operational mission—returning after each flight to land like an aircraft and fly again. On each test flight, *Columbia* satisfied increasing performance demands besides carrying experiments into orbit. STS 3 in March conducted scientific and applications experiments, tested prolonged exposure of the orbiter to extremes of heat and cold, and extended the length of flight to eight days. STS 4 in July carried the first military, commercial, and get-away-special payloads. Although hardware problems canceled planned astronaut activities outside the orbiter, STS 5 met its operational objectives of delivering two communications satellites to orbit—*SBS 3* for Satellite Business Systems and *Anik C-3* for Telesat Canada.

At the end of the year, the second Space Shuttle orbiter, *Challenger*—delivered in July—was being prepared for its first mission, to fly early in 1983. *Columbia* was being modified for the first Spacelab mission, scheduled for late 1983. NASA signed launch service agreements with 10 users in 1982 and continued negotiations with 14 others.

Spacelab. An important milestone in the Spacelab program, the cooperative activity including Europe's major contribution to STS, was reached in July 1982 with European Space Agency delivery of three Spacelab pallets for exposing instruments in Shuttle orbit and a container for the operating electronics. With the 1981 delivery of the Spacelab laboratory module, the July shipment leaves an instrument-pointing system still to be provided under ESA's commitment. The laboratory module will fit into the Shuttle's cargo bay to offer a pressurized, shirtsleeve environment for engineers and scientists in orbit. System and payload integration and crew training continued in preparation for the first dedicated Spacelab mission, planned for the fourth quarter of 1983. This mission will include 40 international experiments and both European and U.S. scientists in the flight crew of six.

Two complements of Spacelab equipment already have flown on the Shuttle, OSTA 1 in 1981 and OSS 1 in March 1982, testing the environment around the orbiter and making scientific observations of the earth and atmosphere.

Shuttle Stages. DoD continued full-scale development of the inertial upper stage (IUS), designed to boost DoD and NASA payloads from the Shuttle's low earth orbit to higher orbits. NASA also began joint development with DoD of a short, wide-body Centaur upper stage and a NASA-funded long, wide-body Centaur for use with the Shuttle. The industry-developed spinning-solid upper stage SSUS-D (also called payload assist module, PAM-D) completed tests during 1982 and launched the two communications satellites from the Shuttle's cargo bay into geosynchronous orbit during STS 5. PAM-D also served as the third stage on expendable Delta launch vehicles for launches of six commercial satellites.

Advanced Programs. NASA continued to study requirements and concepts for expanding the Space Transportation System toward a permanent presence in space. Design-definition studies and advanced development of free-flying, unmanned, low-earth-orbit platforms were completed with private industry. Complementary studies were made in a number of other countries. Other programs included advanced development for a Tethered Satellite System (TSS), to be a cooperative effort with Italy, and preliminary concept studies of a teleoperator maneuvering system (a remotely piloted orbital service vehicle).

Expendable Launch Vehicles

The year's 15 launches on expendable vehicles included a perfect record, with NASA's 9 launches putting 9 satellites into orbit, 8 of them reimbursable (in addition to the 2 put into orbit by the Shuttle). DoD's 6 launches included 2 communications satellites on 1 vehicle, for a total of 7 payloads in orbit. (See table of 1982 launches in appendix A-3.)

Aeronautics

Improvement of Operational Systems

Civilian and military aeronautical development programs made a number of advances in 1982, to improve U.S. operational airborne and airway systems.

Aircraft and Airborne Systems. Among government agencies, the Department of Defense has responsibility for operational aircraft.

BOMBER AIRCRAFT. The four major associate contractors received full-scale development contracts for the modernized, multirole B-1B bomber, part of President Reagan's strategic program announced in 1981.

Rollout for the first production B-1B was scheduled for October 1984, with the first flight in March 1985.

FIGHTER AIRCRAFT. Full-scale development was essentially completed on the multimission F/A-18 Hornet, a naval strike fighter to replace the F-4 fighter and A-7 attack aircraft. The Air Force began studies for an advanced tactical fighter for the 1990s with increased mission flexibility, including short takeoff and landing, greater agility, greater speed and altitude, increased range and payload, better vehicle and weapon integration, and improved reliability.

TRANSPORT AIRCRAFT. The Air Force awarded a low-level development contract for the C-17 transport, including investigation of externally blown flap systems on swept supercritical wings, direct thrust reversers for the entire engine flow, work load for a three-man crew, and a two-pilot cockpit. The project will lay ground work for a follow-on aircraft in the early 1990s.

REMOTELY PILOTED VEHICLE (RPV). The Army's small unmanned air vehicle flew its first flight in July 1982. Four flights demonstrated computer-controlled launch, recovery, and navigation, as well as telemetry to the ground control station. The RPV will perform target-acquisition, designation, aerial-reconnaissance, and artillery-adjustment missions.

HELICOPTERS. The Air Force began a program to develop the HH-60D Night Hawk for combat rescue and special operations forces. The helicopter will make long-range, unescorted flights at night and in bad weather. In the Army program to improve operational characteristics of the medium-lift helicopter, three prototype CH-47Ds had flown some 2200 test hours by the end of the year. Deliveries of the first production aircraft were to begin in 1983. The Army also completed development flight testing of the AH-64 Apache advanced attack helicopter, which will have laser-equipped antitank missiles and sights for day, night, and bad-weather operations.

V/STOL AND V/TOL. The Navy completed the first stages of operational test and evaluation of the AV-8B, an improved, vectored-thrust, vertical or short takeoff and landing aircraft that will double the range and payload performance of the AV-8A. A joint technology assessment reviewed concepts for the planned JVX, a multimission, vertical takeoff and landing vehicle to meet the needs of all the services.

Airway Systems. The Federal Aviation Administration of the Department of Transportation—responsible for the nation's airways—conducts development programs to improve the safety of the airways and airports, increase efficiency of air navigation and traffic control, and ensure the compatibility of air operations with the environment. Many programs are conducted with other agencies, including the Department of Commerce, NASA, and DoD.

AIR SAFETY. FAA, NASA, and the British Royal Aircraft Establishment continued development of an antimisting fuel additive to reduce postcrash jet transport fires, and FAA tested devices for detecting explosives in air cargo and baggage. NASA completed development of an aviation safety reporting system, which it manages for FAA. NASA and FAA also cooperated in research into lightning hazards, wind shear, icing, and advanced fire-resistant materials.

AIR TRAFFIC CONTROL. FAA in January issued a plan for modernizing its air traffic control and navigation system over the next two decades, using higher levels of automation, consolidating facilities, incorporating new surveillance and communication radar systems, and installing the microwave landing system.

Aeronautical Research

Advances in NASA and DoD aeronautical research and development continued in 1982, to uphold U.S. leadership in world air transportation and military aeronautics.

Facilities. NASA completed two major wind tunnels for NASA, industry, and DoD aeronautical testing—one at Langley Research Center in Virginia for advanced transonic testing and one at Ames Research Center in California for testing full-sized rotorcraft and V/STOL aircraft. Repairs were planned for drive fans damaged in a December accident at the Ames facility.

Engines. NASA demonstration of advanced components in a research test-stand engine promised as much as 15 percent reduction in fuel consumption by turbofan engines. Joint Navy-Air Force programs tested advanced gas-generator and low-pressure spool-engine components and studied concepts for early prototype versions of more reliable, large, high-thrust, tactical aircraft engines. Navy and Grumman Aerospace pilots flew two F101 engines on 44 flights of an F-14B aircraft, from mid-1981 into 1982, demonstrating reliable operation and increases in performance.

Aerodynamics. NASA began verification testing of advanced, swept, supercritical airfoils designed to reduce drag and increase efficiency of long-range transport aircraft by improving laminar flow over wings and tail. Research into arrow-wing concepts, wing-fuselage blending, advanced aluminum and composite structures, and improved propulsion components and controls made progress toward longer range and larger payload capability for military supersonic cruise aircraft. Two F-16XL aircraft were flight-testing arrow wings. NASA also began work toward fabricating and ground-testing a large-scale research propeller. Wind-tunnel tests of turboprop wing installations with contour changes to accommodate the swirling slipstream gave promising results. Increased accuracy in computer computations and methods advanced the ability to predict aerodynamic forces and torques, facilitating design and testing.

The Air Force and NASA began flight-testing a modified F-16 advanced-fighter-technology-integration (AFTI) aircraft in July 1982. The test aircraft integrates triple-redundant, digital flight control with vertical canard surfaces for heightened agility and flexibility. Wings for an AFTI F-111 aircraft were being modified with variable-camber airfoil for flight testing in 1983.

Materials and Structures. The joint DARPA-USAF-NASA experimental forward-swept-wing X-29 progressed toward first flight in 1984. Advanced composite materials, aeroelastic tailoring, digital fly-by-wire control, and other advanced technology in the X-29 will decrease aircraft size and weight, reduce transonic drag, improve low-speed flying, and increase transonic and supersonic maneuverability. NASA studied the roles of cobalt in superalloys for gas-turbine engines, seeking alternatives to rare imported materials. Research established technology for understanding buckling and nonlinear response of composite aerospace structures, for suppressing flutter, and for alleviating loads.

Rotor Research. NASA's rotor systems research aircraft (RSRA) completed its first flight-research phase, and the NASA-Army-Navy tilt-rotor research aircraft continued proof-of-concept flights as well as operational demonstration flights for the military services. Other NASA research investigated noise prediction, load prediction, vibration, vortex interaction, and transonic flow. The Army tested a no-tail rotor demonstration aircraft and studied improvements in helicopter autorotation, curved composite fuselage frames, composite materials for helicopter airframes, and rotor noise generation.

Powered Lift. NASA wind-tunnel tests will investigate promising concepts from design studies completed in 1982 for a single-engine, supersonic, short-takeoff and vertical-landing, fighter-attack aircraft. In one concept, remote burning of the engine-fan air stream provides thrust; in another, an ejector provides additional mass airflow for vertical thrust.

Avionics. Engineering models of two fault-tolerant computers delivered to NASA for evaluation promise highly reliable flight-control systems for future aircraft. The Army made progress in developing an advanced digital, optical control system (ADOCS) to increase battlefield effectiveness of helicopters. A redundant digital-optical system is to be as electrically passive as possible to avoid electrical interference.

Space Energy

Department of Energy-supplied nuclear-electronic systems have provided power for many NASA and DoD satellites and planetary probes. DOE continued research in 1982 to develop lightweight, safe, nuclear isotopes and reactors for higher power requirements of future space missions. NASA also supports DOE in applying aerospace expertise to energy technology for use on the earth.

Energy for Use in Space

DOE fabricated two thermoelectric converters in 1982. The advanced general-purpose heat-source radioisotope thermoelectric generators (GPHS-RTGs) will be used for the *Galileo* and International Solar Polar Mission (*ISPM*) spacecraft to study Jupiter and the sun. Testing of an engineering unit began. Fuel, iridium, and graphite components were produced. DOE also began testing two models of an adaptable, modular, isotopic thermoelectric generator promising substantially higher specific power than that of present RTGs.

Energy for Use on Earth

NASA developed technology for automotive gas turbines, the Stirling engine, and electric and hybrid motor vehicles. Wind turbines sponsored by NASA, DOE, and the Department of the Interior provided valuable data for evaluating the efficiency and economy of producing electrical energy from the wind. NASA also made progress in research toward cost-competitive, long-life solar arrays and solar concentrator dishes for converting solar energy to electricity.

National Aeronautics and Space Administration

The National Aeronautics and Space Administration was established in 1958 as the civilian agency charged with planning, directing, and conducting research and exploration in space and aeronautics. NASA cooperates with other federal, state, local, and foreign governments that have interests in these fields. Its activities with the Department of Defense are particularly extensive, since DoD is responsible for coordinating the nation's military space and aeronautics programs.

NASA's goals in space are to develop technology to make operations more effective; to enlarge the range of practical applications of space technology and data; and to investigate the earth and its immediate surroundings, the natural bodies in our solar system, and the origins and physical processes of the universe. In aeronautics, NASA seeks to improve aerodynamics, structures, engines, and overall performance of aircraft, to make them more efficient, more compatible with the environment, and safer.

Applications to the Earth

NASA applied space research and technology to specific needs on earth in a broad spectrum of programs in 1982. It emphasized advanced technology for space communications, gathered data from space on physical and chemical processes in the atmosphere and oceans, tested improved techniques for monitoring the earth's resources and its crustal and polar motion, and cooperated with industry to experiment in processing materials in space.

Communications

Advanced Research and Development. NASA in 1982 refocused its space communications program on high-risk technology to ensure continued U.S. preeminence in the field. The technology developed will be usable in multiple-frequency bands and in a wide range of future communication systems required by NASA, other government agencies, and U.S. industry. The proof-of-concept and base research technology already under development in NASA's previous program will form the foundation of its restructured program—including multibeam, frequency-reuse antennas; baseband processors; high-speed, high-bandwidth crossbar switches; digital and microwave integrated circuits; intersatellite links; and multipower transmitters.

The first segment of the new program to be tested in orbit will emphasize high-gain multibeam antennas. Development of the Advanced Communications Technology Satellite (*ACTS*) for flight experimentation is planned to begin in 1984, with a launch in 1988.

Search and Rescue. To begin a 15-month demonstration and evaluation of the international satellite-aided search and rescue project, COSPAS-SARSAT, the Soviet Union on 30 June 1982 launched *Cospas 1,* the first spacecraft carrying instruments specifically to determine the position of ships and aircraft in distress. Launch of the SARSAT spacecraft (the U.S. satellite NOAA-E) is scheduled for early 1983. NASA is lead agency for the United States, with Canada and France also participating. Other planned participants in evaluating the project include Norway, Sweden, the United Kingdom, and possibly Japan. Although not yet operational, the project has already aided a number of rescue actions, including maritime rescue of eight men after two boat accidents.

Environmental Observations

Upper Atmosphere. The Solar Mesosphere Explorer *SME,* launched in October 1981, continued to measure the flux of incoming solar radiation in the ultraviolet spectral region, ozone in the stratosphere and mesosphere, and other minor constituents, including nitrogen dioxide. The data are expected to improve understanding of physical and chemical processes in the earth's stratosphere and mesosphere.

The first year's data from the *Nimbus 7* research satellite, launched in October 1978, have been archived. The data—from the limb infrared monitor of the stratosphere, the scanning-backscattered-ultraviolet/total-ozone-monitoring spectrometer, and the stratospheric and mesospheric sounder—are being used with data from other satellites and nonsatellite experiments to improve knowledge of the earth's stratosphere. The spectrometer and the sounder are still returning valuable information.

NASA reported to Congress and the Environmental Protection Agency in January 1982 (as required by the Clean Air Act amendments of 1977) an assessment of what is known about key processes in the stratosphere, especially about the effect of man-produced chemicals on the ozone layer. The assessment was developed from the findings of a workshop sponsored by NASA and the World Meteorological Organization, in which some 115 scientists from 13 countries participated. The scientists concluded that a continued release of chlorofluorocarbons (CFCs) 11 and 12 (Freon-11 and -12) at 1977 rates would decrease total global ozone by five to nine percent by about the year 2100, but the effects of other changes in atmospheric composition could modify that result. Increasing concentrations of nitrogen oxides, carbon monoxide, carbon dioxide, and methane over that period must be taken into account before effects of the CFCs can be predicted with greater confidence.

The SAM II instrument on *Nimbus 7* observed stratospheric clouds during recent Arctic and Antarctic winters. Previous reports of stratospheric clouds and haze have been rare, but these measurements show the clouds to be far more abundant than had been assumed. They are observed when stratospheric temperatures are very low, at altitudes up to about 23 kilometers. These clouds are now believed to affect radiation distribution significantly at stratospheric altitudes and to serve as a major sink for polar water vapor.

Lower Atmosphere. The measurement of air pollution from satellites (MAPS) experiment, a gas-filter radiometer for remote detection of carbon monoxide in the atmosphere, acquired 32 hours of data between 38°N and 38°S on the second flight of the Space Shuttle in November 1981. Preliminary analysis suggests that MAPS provided excellent observations of the global distribution of carbon monoxide, a key trace constituent of the earth's troposphere.

Global Weather. The first global experiment of the Global Atmospheric Research Program (GARP) yielded global temperature profiles, sea and land surface temperatures, cloud heights, cloudtop temperatures, fractional cloud-cover, and sea-ice extent for a two-month period. These global fields, along with operational temperature retrievals and cloud-tracked winds, significantly increased the accuracy of numerical weather forecasting. Preliminary indication is that temperature retrievals are the largest contributor to this improvement.

Oceanic Processes. The *Seasat* Data Utilization Project, completed in 1982, converted all data into geophysical units (ocean wave height, topography, surface wind speed, sea surface temperature, etc.) and archived them with the National Oceanic and Atmospheric Administration's Environmental and Data Service. NASA began an extensive oceanographic research program using these rich data. The *Seasat* project demonstrated for the first time that we can produce global data on winds, waves, and temperature. The Pilot Ocean Data System began operation at Jet Propulsion Laboratory, giving the oceanic research community easy access to data from *GEOS 3, Nimbus 7,* and *Seasat* satellites.

Development began in 1982 on in situ instruments to provide subsurface oceanic observations complementing observations from space. Techniques include surface and subsurface drifting buoys; subsurface, acoustic and optical plankton measurements. Measurements will aid in determining the general circulation of the ocean and its effect on global climate and in measuring the primary (plant) productivity of the global ocean and its effect on the food chain.

Resource Observations

Observations from the Shuttle. The Space Shuttle's first scientific payload—called OSTA 1 for NASA's former Office of Space and Terrestrial Applications—was carried into orbit on the Shuttle orbiter *Columbia's* second test flight, in November 1981. Analyses in 1982 found that it obtained useful remote-sensing data for the study of continental geology, atmospheric chemistry, physical oceanography, meteorology, and marine biology. The radar experiment obtained more than 10 million sq km of surface imagery. The two multispectral sensors designed to map chlorophyll concentrations in the open ocean and to detect chemical variations of geological materials in land areas performed flawlessly. A fourth instrument made the first global survey of carbon monoxide abundance in the earth's atmosphere (see "Lower Atmosphere," above).

The Shuttle imaging radar-A (SIR-A) not only obtained clear, detailed imagery of the earth's surface through cloud cover and darkness, but also returned images of features beneath the surface in some very arid areas. SIR-A penetrated the dry, almost featureless Selima Sand Sheet in the eastern Sahara Desert to reveal previously hidden river channels and geologic structures. Some subsurface features may be up to 50 million years old. Ancient, now-vanished river systems may help explain present-day features, and the new radar tool may aid the search for water and other resources in this area. The radar imagery also uncovered new linear features associated with regional faulting in Indonesia, China, and the eastern United States; significant structural detail beneath forest cover in remote areas of western Guyana; and composition of the surface layer in the Great Kafir Salt Desert of Iran.

Three experiments compromised by the shortened STS 2 mission were rescheduled for later flights. Analysis of OSTA 1 radar imagery indicated a need to change the look angle of the radar's antenna to image other features of interest. Equipment flown on OSTA 1, modified to provide that capability, is scheduled to fly on the Shuttle in late 1984. Before the advent of the

Shuttle, recalibration, modification, or upgrading of experimental sensors that had orbited the earth was not possible. The Shuttle's ability to carry instruments into space routinely and return them to the ground has the potential to accelerate remote-sensing research and promote eventual commercialization of the technology.

Renewable Resources: AgRISTARS. NASA participates in the multiagency Agricultural and Resources Inventory Surveys through Aerospace Remote Sensing to develop and test spectral analysis of remotely sensed data acquired from experimental sensors such as the Landsat multispectral scanner (MSS) and the thematic mapper. Designed primarily to meet information needs of the Department of Agriculture but also for global assessments for other agencies and scientists, the program made technical progress in all projects during 1982. The most significant developments were in rapid, large-scale crop identification and area measurements and in continued development of models of the greenness profile. The models calculate the rate of crop greenup from all four Landsat multispectral-scanner bands over a growing cycle (two or more acquisitions) and have facilitated identification of the crop and its stage of growth. Software improvements reduced analyst time for analyzing 9- by 11-km segments from 5 hours to 15 minutes and central-processing-unit time from 1 hour to 13 minutes. Present results obtained from simulated thematic-mapper data promise much improved distinction of corn from soybeans at earlier stages of growth, with fewer data acquisitions, and accommodation of a wider range of agricultural conditions. NASA participation in AgRISTARS will be phased out by 1984. However, NASA plans to continue fundamental remote-sensing research and development of techniques for extracting information from remotely sensed data.

Renewable Resources Research. Research continued in remote-sensing science and discipline science. Discipline science focused on developing techniques for using the thematic-mapper simulator (TMS) and *Landsat 4* thematic mapper (TM) in vegetation monitoring, hydrology, and geography, seeking to determine new capability and improvements over the MSS and identify the contributing sensor characteristics. Three discipline science research projects were completed: Irrigated Land Assessment for Water Management, Monitoring Insect Defoliation of Hardwood Forests, and Crop Classification Employing Soil Data. Eight projects will be continued, seven of them developing thematic-mapper techniques and one with Japan in hydrology. Research in techniques for large-scale vegetation monitoring and biomass assessment is being conducted with the *NOAA 7* advanced very-high-resolution radiometer (AVHRR), with test sites in Africa and Brazil.

Nonrenewable Resources Research. Emphasis in the nonrenewable resources program was on extracting different kinds of geological information from remote-sensing measurements in different spectral regions. Analysis of experimental data collected during the November 1981 Shuttle flight was completed. The Shuttle multispectral infrared radiometer (SMIRR) experiment showed that narrowband spectral measurements in shortwave infrared can detect subtle differences in clay minerals, distinguishing clay minerals produced by normal weathering from those commonly associated with subsurface deposits of base and precious metals.

Landsat Operations. Landsat 4, launched 16 July 1982, replaced the aging *Landsat 3* for remote sensing of earth resources, pollution, topography, and geology from space and is also testing a new sensor, the thematic mapper. Images received have exceeded the expectations of engineers and scientists. The new satellite's success to date introduces a new chapter in remote-sensing technology, a technology rapidly becoming of prime importance to farmers, foresters, urban planners, and oil companies. The spacecraft continues the work of the earlier Landsats and also advances remote-sensing technology, testing improved spatial resolution, new and narrower spectral bands, and improved radiometric resolution. The instrumentation built into *Landsat 4*'s thematic mapper will be compared with the flight-proved multispectral scanner used on earlier Landsats and also carried on *Landsat 4*. Information from the two instruments will be analyzed in a variety of studies.

Land-Remote-Sensing Test and Evaluation. NASA seeks to determine the viability of experimental remote-sensing techniques for resource management in diverse test settings and to provide information on them for further research and development. New technology in remote sensing has been validated as producing useful management tools through cooperative projects with private industry, state and local governments, and universities. The program has tested experimental techniques pertinent to resource management issues of national concern and carried out projects in cooperation with technically advanced user organizations.

During the past year, six land-remote-sensing test and evaluation projects were completed: Olympic National Park fire assessment and fire-behavior modeling, electric-utility transmission-line siting, Appalachian lineaments analysis to identify and map Devonian-shale gas deposits, subarctic land-capability analysis, critical-area management of subtropical water resources, and nuclear-power-plant siting and power forecasting. In addition, nine state and regional applications projects were completed in fields as diverse as wildlife habitat assessment, water demand of irrigated lands, forest resource assessment, and planning for coastal-zone development. These projects transferred NASA remote-sensing technology to some 30 states in the past six years.

Geodynamics. Since 1979, NASA, NOAA, U.S. Geological Survey, National Science Foundation, and Defense Mapping Agency have cooperated in studying the crustal motion of the earth and researching earthquakes. The program uses laser ranging to satellites and the moon, microwave interferometry with astronomical radio sources, and radio transmission from satellites (such as those in the Global Positioning System) for precise measurements of crustal motion and rotational dynamics of the earth. A principal aspect is the study of crustal deformation in the continental United States and Alaska, focusing on the San Andreas Fault in California. Studies of the tectonic plates and the earth's global gravity and magnetic fields also seek understanding of dynamic processes in the solid earth.

During 1982, the program obtained significant new information about the earth. Studies on regional, continental, and intercontinental scales are helping to elucidate basic scientific questions regarding tectonic processes and their relationship to crustal hazards such as earthquakes. In the long term, such studies contribute to social and economic considerations related to forecasting earthquakes and to national security (70 percent of the U.S. semiconductor industry is in earthquake-prone areas of southern California.) The U.S. activity has led to similar studies in some 20 countries and international scientific organizations. Some countries—such as the Federal Republic of Germany, The Netherlands, Japan, and Italy—have or are acquiring similar measurement systems through commercial sources in the United States.

The study of variations in the earth's polar motion, length of day, and the gravity and magnetic fields are contributing to understanding the structure and motion in the earth's interior. Recently, changes in day length have been correlated with changes in the total angular momentum of the atmosphere, and changes in day length and the magnetic field's rate of westward drift have been related to long-term climatic change. The interaction of the solid earth with the earth's atmosphere and with changes in solar energy provide intriguing possibilities—once they are understood—for forecasting weather and climate. The earth's gravity and magnetic fields offer two of the few ways available to "look into the earth" for scientific purposes. Studies are providing new practical information that contributes to the assessment of the earth's natural resources, to navigation, and to operations in space.

Materials Processing in Space

On STS 4, the United States took a big step toward commercial use of the low gravity of space to improve the separation of biological materials and to produce new pharmaceuticals for treating human disease. The experiment was the first commercially funded apparatus to fly on the Space Shuttle. McDonnell Douglas, which proposed and built it under a joint endeavor agreement with NASA, reported that all mission objectives of the test were met.

Continuous-flow electrophoresis, which separated the biological materials, has been used on the earth for many years; but the effects of gravity, primarily sedimentation and buoyancy of the starting mixture, reduce efficiency. Operation in low gravity during the Shuttle flight yielded a 460-fold increase in processed material over the amount that can be produced on the earth, as well as a 5-fold increase in purity. On the sixth flight, an increase in applied voltage is expected to increase the processing volume 560 times over that of an earth-based unit. Samples used for these tests consisted of different concentrations of albumin mixtures (difficult to separate on the earth) and several concentrations of a typical cell-culture medium containing products of commercial interest.

Science

Space science investigates the origin and evolution of the universe, of the solar system, and of life in the universe, as well as the processes that shape the environment of the earth. Use of space technology and the space environment advances knowledge in medicine and biology.

Study of the Sun and Its Earth Effects

Solar-terrestrial physics investigations seek an understanding of the processes controlling the near-space environment. Energy from the sun, arriving in the vicinity of the earth as electromagnetic energy and the plasma flow of the solar wind, influences the atmosphere, ionosphere, and magnetosphere, as well as the earth's weather, climate, auroral display, and radio disturbances.

Three atmosphere explorers—*Explorer 51*, launched in 1973, and *Explorer 53* and *54*, launched in 1976—are studying the interaction of solar ultraviolet energy with the earth's atmosphere, an interaction that produces the ionosphere. The International Sun-Earth Explorers *ISEE 1, 2,* and *3,* launched in 1978, study the interaction of the solar wind with the outermost parts of the earth's magnetic field, an interaction that fills the outer magnetosphere with "hot" plasma. Dynamics Explorers *DE 1* and *2,* launched in 1981, are studying the interaction between the "cool" plasma of the ionosphere and the hot plasma of the magnetosphere.

DE 1 is furnishing spectacular pictures of the entire auroral oval in several wavelengths. The details revealed correlate with the particles and fields directly measured by *DE 2,* permitting thorough study of the generation of the aurorae and the influx of energy from high altitudes. A Fabry-Perot interferometer measures the altitude profiles of large-scale winds that affect the distribution of energy and chemical constituents in the earth's environment. Close relationships between the measured electric and magnetic fields will eventually help us understand some of the large-scale dynamo and motor effects that have been theoretically postulated, but could not be systematically studied till now.

Communication with *Helios 1,* lost in August, was restored in November. The spacecraft's approach nearer the sun increased solar-cell power sufficiently to sustain the signal. Launched in 1974 as a joint U.S.-West German mission, *Helios 1* investigates the close-in solar environment and the sun itself.

Study of the Planets

NASA's deep-space vehicles in other parts of the solar system continued to work well and return data. These included *Pioneer 10* and *11* (launched in 1972 and 1973), the *Pioneer-Venus 1* orbiter (launched in 1978), and *Voyager 1* and *2* (launched in 1977)—which have all already made valuable discoveries about the planets. *Voyager 2* will encounter the planets Uranus in January 1986 and Neptune in 1989, while *Voyager 1* will continue on a trajectory out toward the heliospheric boundary. Plans to launch the *Galileo* spacecraft in a cooperative project with Germany and the European International Solar Polar Mission (*ISPM*) in cooperation with the European Space Agency (ESA) are proceeding well despite changes in launch years from 1984 to 1986 for *Galileo* and from 1985 to 1986 for *ISPM. Galileo* will reach Jupiter late in 1988. *ISPM* will acquire data about the sun from above the ecliptic plane.

In the near term, the planetary exploration program faces a hiatus in the return of major new scientific information between 1982 and 1988. However, the reflight of the OSS 3 payload on the Shuttle in 1985 to observe Halley's Comet, U.S. participation in the European *Giotto* mission to observe that comet, the ground-based International Halley Watch activities, and the retargeting of *ISEE 3* for an encounter with the short-period comet Giacobini-Zinner will make valuable scientific contributions.

Study of the Universe

The NASA astrophysics program investigates the physical nature of the universe, from our own sun outward to the most distant quasars. It seeks 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, and so we must carry the instruments into space.

Space Telescope. The *Space Telescope* will be our first major observatory in orbit. Being developed for launch in the mid-1980s, it will permit us to see farther into the universe than ever before and is expected to have a revolutionary influence on our understanding of the universe. The *Space Telescope* will image astronomical bodies with at least 10 times finer resolution than can be achieved by telescopes observing through the earth's atmosphere, and it will detect objects 50 times fainter than can the largest ground-based observatories. Development of the telescope and its focal-plane instruments during 1982 shifted from design to manufacturing, assembly, and testing. Fabrication of flight hardware began. The primary mirror, whose surface departs from a perfect figure by no more than a few millionths of an inch, was completed. The secondary mirror was ground, polished, and coated. This mission is also a cooperative project with ESA.

High Energy Astronomy Observatories. The study of supernova remnants in 1982 benefited greatly from analyses of observations made by *HEAO 2* and *HEAO 3* satellites (operating from 1978 and 1979 into 1981, more than twice their designed lives). Remnants are portions of supernovas that are violently ejected into space and subsequently interact with, and heat, the ambient interstellar medium. *HEAO 2* x-ray images of supernova remnants revealed a complex and asymmetric structure at the shock front, indicating strong non-uniformities in the interstellar medium. Both broadband and high-resolution spectral observations by *HEAO 2* showed a wealth of x-ray emission lines that yielded valuable information on the elemental components, the temperature, and the equilibrium state of the expanding shell of ejecta plus swept-up medium. *HEAO 3* cosmic-ray measurements gave additional information on the production of heavy elements released during the supernova explosion. The relative abundances of elements measured with the heavy-nuclei experiment on *HEAO 3* indicate that the "r process," in which heavy elements are produced in a rapid nucleosynthesis episode during the supernova explosion, is inconsistent for the synthesis of elements through nuclear charge 40 for zirconium.

Gamma Ray Observatory. One of the instruments planned for launch on the *GRO* satellite will extend the study of supernova remnants to the search for gamma-ray line emission from radioactive nuclei ejected in the initial explosion. *GRO* is proceeding toward expected launch readiness by May 1988. It will make observations in the center of our galaxy, as well as nuclear chemistry studies of astrophysical objects and the origins of gamma-ray bursts. TRW completed the extended definition study in September. The phase D development contract award was planned for early 1983. Considerable emphasis has been placed on instrument development, and electronics design is 50 to 80 percent complete on the four instruments.

Solar Maximum Mission. With receipt of approval of the Solar Maximum Repair Mission, activities are going ahead rapidly to perform this mission in early 1984. The repair will include an in-orbit exchange of the attitude-control-system module of the multimission modular spacecraft that carries *SMM,* as well as three repairs of the science instruments. This mission will test several important capabilities of the Space Shuttle, including use of the manned maneuvering unit and the remote manipulator system for capture and redeployment of the *SMM* spacecraft. Meanwhile, the three operating instruments on *SMM* continue to return exciting data. The radiometer experiment has discovered the first definite evidence for changes in the heat output of the sun, observing a very small drop in solar output over the two-year lifetime of *SMM* so far. This drop coincides with a drop in the sunspot number, as we pass out of the period of peak solar activity, and will lead to many studies of the relation between sunspots and solar heat output. The gamma-ray instrument has also made important discoveries about solar flares, including detection of many new nuclear reactions in flares and the first observations of neutrons, one of the basic constituents of all matter, created in flares.

Explorers. The Infrared Astronomy Satellite *IRAS,* an Explorer-class satellite to be launched in January 1983, will make an all-sky survey to identify the important infrared emitters in the universe spanning the wavelength range of 8-120 micrometers. A cooperative effort of the United States, Netherlands, and United Kingdom, the program will publish a catalog of the celestial sources identified, giving their position and fluxes.

Development began during fiscal 1982 on the Cosmic Background Explorer *COBE,* with a launch planned for 1989. The mission is to make a definitive exploration of the diffuse radiation of the universe between the wavelengths of 1 micrometer and 13 millimeters. This band includes the 3-kelvin cosmic background radiation thought to be the remnant from the hot Big Bang that is assumed to have started the expansion of the universe. The infrared band (1-300 micrometers) may contain the dominant portion of the universe's energy content, including radiation from primeval galaxies.

Suborbital Observations. In addition to standard sounding rocket and balloon payloads, NASA is developing a carrier for sounding rocket payloads that will use the Space Shuttle. The "Shuttle payload autonomous research tool for astronomy" (SPARTAN) will provide experiment flight times of up to 40 hours at costs comparable to those of present sounding rocket missions. Three of these payloads are already on manifests for STS missions.

The NASA balloon program makes extensive use of the National Scientific Balloon Facility at Palestine, Texas, funded and managed by the National Science Foundation. NASA and NSF signed an agreement under which NASA assumed funding and management for the facility beginning in fiscal 1983.

Advanced Technology Development and Long-Range Planning. Advanced technology development continued on the Advanced X-Ray Astrophysics Facility (*AXAF* satellite) with contracts to Perkin-Elmer and Itek Corporation for development of advanced x-ray mirrors. Contract work by Perkin-Elmer also continued on advanced technology development of the Solar Optical Telescope (SOT), to be carried on several future Space Shuttle flights. The National Academy of Sciences, advising NASA, published an assessment of future needs in its *Astronomy and Astrophysics for the 1990's* (NAS, 1982). This third decennial study of the subject by NAS was addressed to both NASA and NSF and proposed priorites for new programs ranging across all disciplines in those fields.

Life Sciences

Operational Medicine. Biomedical studies of flight crews on operational Space Shuttle flights, which began in November 1982, will provide information on effects of repeated and prolonged spaceflight, human adaptability, human environmental needs, and health maintenance. Experiments will also fly on shared Spacelab missions on the Shuttle, and Spacelab 4 will be dedicated entirely to life science investigations. Spacelab 1, scheduled for October 1983, will include NASA measurements of cosmic radiation inside Spacelab, as well as studies of space motion sickness and sensory motor adaptation to weightlessness, spinal reflexes and posture changes during weightlessness, space effects on the body's immune response (ability to resist disease), and mass changes in red blood cells. NASA will also study plant growth in space to see if circadian rhythms persist and to see how very low gravity affects growth movements. The European Space Agency (ESA) is sponsoring six complementary experiments on Spacelab 1.

The Spacelab D-1 mission, scheduled for 1985, is a German mission with some U.S. life sciences participation. Vestibular research on motion sickness will continue on that mission. Spacelab 2 and 3, both planned for 1984, will flight-test plant-growth units, and animal holding facilities in preparation for the 1985 flight of Spacelab 4. Some 25 experiments will fly on the dedicated life sciences SL 4 mission, investigating gravitational biology, vestibular adaptation and motion sickness, cardiovascular and cardiopulmonary adaptation, fluid-electrolyte adaptation, red-cell mass loss in blood, muscle and bone degradation, and immunological changes. Research animals (rats, mice, small monkeys) will be a part of the inflight experiments.

Integration of subsystems in preparation for SL 1 was under way at Kennedy Space Center in 1982. Mission planning and preparation for the next four flights intensified. Principal investigator contracts were negotiated, with final selection for SL 4 due early in 1983. Hardware development began. Ground facilities at the NASA centers were completed in 1982, and most of the design for a data-collection and handling facility was completed.

Biomedical Research. Half the crew members flying on the Shuttle orbiter have experienced space motion sickness, a self-limiting vestibular disorder marked by nausea and occasional vomiting. Symptoms usually occur shortly after crews enter weightlessness, increase over several hours, and then gradually subside over the next two or three days. Because Shuttle flights are short, motion sickness may prevent completion of mission tasks. Present medication appears helpful but not adequate. Ground tests are not yet able to make useful predictions as to who will become ill. NASA therefore is planning to form a Vestibular Program Office to accelerate and focus research. The first two-year phase of testing new technology and procedures on Shuttle flights seeks to improve management of motion sickness by 10 to 15 percent.

Space Biology. Plant experiments flown on the third Shuttle mission and ground-based research with recently developed scientific techniques and instruments are providing a foundation for cultivating plants in space. They also have contributed significantly to plant science. Plants grown in the mini-greenhouse flown on STS 3 were markedly disturbed in orientation, showed reduced root-cell division, and suffered serious chromosome damage. Ground research found that a complex biochemical mechanism including calcium movement, an ion gradient, and a plant hormone (auxin) modifies plant response to gravity. Understanding the mechanism in physiological, morphological, and behavioral responses is now within our grasp. Experiments on the Shuttle missions should rapidly advance research. The effects on plants of gravitational changes doubtless affect harvest and biomass yield, factors of importance to cultivating plants both in space and on the earth. No one has yet succeeded in growing a plant from seed to seed in space but, for a closed-loop, water-oxygen-nutrition system in a space station, growing plants in space will be critical.

Preparations continued during 1982 for NASA's participation in the Soviet Union's Cosmos biological satellite mission now scheduled for launch in late 1983. The Soviet spacecraft will fly two rhesus monkeys for approximately one week in space, and U.S. scientists will assist in cardiovascular and biorhythm measurements of the primates, as well as postflight data analysis. U.S. specialists also plan to participate in studies of calcium metabolism, vestibular system, and behavior of laboratory rats, also to be flown on the Cosmos mission.

Global Biology. A new program began studying the influences of biological processes on global biogeochemical cycles. Biological processes dominate in the production and removal of many constituents of the biosphere, and understanding these processes is critical to understanding the consequences of environmental perturbations. Analytical modeling will be used to specify needs for new field research, remote-sensing observations, and further analyses of existing data. Progress in these research areas will progressively refine models of interactions between the biota and the biosphere. In 1982, the program began to develop methodologies for recognizing ecosystem borders and estimating biomass in selected regions using remote-sensing data. Other research—on biogenic methane production in selected wetland regions—indicated that these ecosystems can act as both major sources and sinks of atmospheric methane as determined by seasonal temperature and precipitation variability.

Spacelab Flight Program

The third flight of the Shuttle orbiter *Columbia,* in March 1982, carried a Spacelab pallet of scientific instruments, designated OSS 1 for the former Office of Space Science. The instruments measured the environment of the orbiter, electromagnetic and particulate contamination surrounding it, and solar polarization and irradiance. Detailed information obtained will help to perfect operation of a more powerful electron accelerator for studies on later Shuttle flights. Detection of electronic and ionospheric characteristics proved that the orbiter's electronic emissions would not prevent sensitive scientific measurements planned for later missions.

Integration and testing of Spacelab 1 payload components began at Kennedy Space Center in 1982. Spacelab's long module and pallet, built by the European Space Agency, were delivered in December 1981. During the first half of 1982, scientific instruments for studies in astronomy and solar physics, space plasma physics, atmospheric physics and earth observations, life sciences, and material sciences were delivered to KSC. Instrument testing began in August. Integration of the assembled Spacelab module into the Shuttle would begin in early 1983 for a fall launch.

Space Transportation

Space Shuttle

NASA, with DoD participation, is developing the national Space Transportation System (STS) to provide the United States an economic and efficient capability for moving personnel, equipment, supplies, and scientific, commercial, and other payloads into and out of space. The Space Shuttle—the first reusable earth-to-orbit vehicle—made three flights in 1982. The first two missions, STS 3 and STS 4, completed the four-flight orbital-test program, which began in 1981 and demonstrated the Shuttle's readiness for routine space operations. STS 5, the Shuttle's fifth flight and the third in 1982, introduced the STS operational era.

STS 3 completed an eight-day mission in March. The mission achieved its objectives of demonstrating performance of the Shuttle orbiter under conditions more demanding than in the earlier flights, conducting long-duration thermal-soak tests (prolonged exposure to extremes of heat and cold by turning different surfaces of the craft toward the sun), and extending the length of orbital flight. The orbiter *Columbia* landed at the White Sands Test Facility because heavy rains had made the primary landing site at Dryden Flight Research Facility unusable. A severe windstorm delayed the landing one day and wind-blown gypsum dust following the landing necessitated disassembly of some of the orbiter's reaction-control vernier engines for cleaning before the next mission. *Columbia* was returned atop its 747 carrier aircraft to Kennedy Space Center to begin processing for STS 4.

Launched in June, STS 4 carried the first military, commercial, and get-away-special payloads, moving the Shuttle closer to a national space transportation system capable of fulfilling government-wide and other user requirements. All systems performed satisfactorily except the solid-fueled rocket boosters' recovery systems, which permitted the boosters to sink in the ocean on their reentry. Achievement of mission objectives, similar to those for STS 3, further demonstrated orbiter performance under increasingly demanding conditions. After the seven-day STS 4 mission, *Columbia* touched down at Edwards Air Force Base, California, on 4 July 1982, making its first landing on a concrete runway. The three prior landings were on dry-lake-bed runways that permitted long ground runs if needed. President and Mrs. Reagan watched the landing and welcomed the two returning astronauts. *Columbia* was ferried to KSC for its next flight.

The five-day STS 5 mission, the first operational flight of the Space Shuttle, was completed in November. For the first time *Columbia* was manned by four astronauts, instead of two. Touchdown was again at Edwards Air Force Base. The mission achieved its operational objective of delivering two commercial communications satellites to low earth orbit for subsequent boost into geosynchronous orbit. A planned EVA demonstration test was canceled because of spacesuit hardware problems.

During 1982, the mission control center and Shuttle mission simulation at Johnson Space Center supported the STS missions, including NASA, DoD, and commercial payload operations.

Orbiter. The Space Shuttle orbiter flew its three 1982 missions with no major problems. Each mission expanded the flight envelope further, testing more fully the capabilities and characteristics of the orbiter. The time required to prepare *Columbia* for its next mission decreased with each test flight. Another major milestone in 1982 was delivery of orbiter OV-099, *Challenger,* lighter than *Columbia* and incorporating more crew and passenger space as well as changes developed from *Columbia*'s missions. *Challenger,* delivered to KSC on schedule in July, was to make its first flight in early 1983.

Following its fourth flight, *Columbia* was modified at KSC for the November operational flight and, at the end of the year, was being modified again for the first Spacelab mission, now scheduled for September 1983.

Main Engine. The Shuttle orbiter's three high-performance hydrogen-oxygen main engines each have a rated vacuum thrust of 2000 kilonewtons (470 000 pounds). A major advance in propulsion technology, the engines are designed to provide a long operating life (7.5 hours, 55 starts), and the thrust can be throttled over a wide range (65 to 109 percent of rated power level) as required.

An electronic digital controller—the first to be used in a rocket engine—accepts commands from the orbiter for engine start, shutdown, and throttle-setting changes and monitors engine operation. It automatically adjusts performance and can shut down the engine safely should specific failures arise.

The engines performed flawlessly during the first five flights of *Columbia.* Postflight inspection revealed no significant discrepancies. A higher-thrust version of the engine (109 percent of the present rated power level) had been tested for more than 35 000 seconds by the end of 1982. Flight-certification testing of the full-power-level design was scheduled for completion by February 1983.

External Tank (ET). The external tank carries 700 000 kilograms of liquid-hydrogen and liquid-oxygen propellants for the orbiter's three main engines. The tank, 46.8 meters long and 8.4 meters in diameter and the only expendable portion of the Space Shuttle system, separates from the orbiter before orbit insertion and breaks up during descent over a remote ocean area. The external tanks performed well in the three 1982 launches. During the year, four tanks were delivered to KSC, including the last tank (ET-6) of the original configuration and the first lightweight tank (LWT-1). LWT-1, 3600 kilograms lighter than the earlier models, was delivered in September, ahead of schedule. Eight other lightweight tanks are in production at the Michoud Assembly Facility.

Solid Rocket Booster (SRB). Two solid-fueled rocket boosters burn for about two minutes in parallel with the orbiter's main propulsion system to provide thrust for initial ascent. The two boosters provide a combined thrust of 23 600 kilonewtons (5.3 million pounds). They are 4.5 meters in diameter, 45.5 meters long, and together weigh 583 600 kilograms at launch.

Flight performance of the SRBs for STS 3, 4, 5 was within specification. Descent and recovery were as planned in STS 3 and 5. The STS 5 aft skirts, strengthened by modifications of the internal stiffener rings, suffered less damage when they struck the water than did skirts on the earlier flights. In STS 4, the boosters struck the water with much greater force than they were designed to withstand, broke up, and sank. An investigation board concluded that one of two risers that attach the chutes to the SRB on each of the six main chutes was prematurely disconnected. The decelerator system, designed to release the main chutes at water impact to facilitate recovery, had released them too soon. The STS 5 recovery system was modified to eliminate severance of the main chutes at water impact.

Development progressed on two motors that will increase the payload capabilities of the Space Shuttle. The first of two static firings of a high-performance motor (which permits a 1360-kilogram payload increase) was completed in October 1982, with a second scheduled in the spring of 1983. Work also began in 1982 on design, development, and test of the filament-wound case motor (2495-kilogram payload increase) scheduled for its first flight in late 1985 from Vandenberg Air Force Base. Assembly of boosters for STS 3 through STS 8 proceeded, along with the high-performance motor and refurbishing of three sets of hardware for future flights. A series of production readiness reviews continued in 1982.

Launch and Landing. Shuttle processing and the launching of the third, fourth, and fifth flights of *Columbia* were supported by the first line of processing facilities at KSC while construction and activation of the second line were in process. Two major work stations in the second line—the Orbiter Processing Facility bay number 2 and mobile launch platform number 2—were completed in 1982 and processed *Challenger* for its early 1983 launch. A complete line of processing and launch facilities under construction at Vandenberg Air Force Base in California was on schedule for the first planned Shuttle launch from there in 1985.

Inertial Upper Stage (IUS). Full-scale development of the IUS continued in 1982. Being developed by the Department of Defense to extend the reach of the Shuttle into higher earth orbits, the solid-propellant IUS and its payload will be deployed from the orbiter in low earth orbit, and the IUS will boost the payload to a higher-energy orbit. NASA and DoD will use the IUS primarily for geosynchronous missions. NASA is coordinating non-DoD requirements with the DoD program to ensure IUS utility for NASA and commercial applications. The first Shuttle/IUS was to launch a Tracking and Data Relay Satellite in early 1983.

Centaur. NASA initiated contracts for development and procurement of two wide-body Centaur upper stages for launching the *Galileo* and International Solar Polar (*ISPM*) missions in May 1986. The wide-body STS Centaur is a modified version of the existing Centaur upper stage, which has flown successfully as part of the Atlas-Centaur expendable launch vehicle program. To achieve high reliability at minimum cost, the wide-body version uses the same propulsion system and about 85 percent of the existing Centaur's avionics systems. The propellant tanks are modified to add 50 percent more capacity and to make the stage compatible with the Shuttle.

Spinning Solid Upper Stage (SSUS). The SSUS's are being developed and sold as commercial ventures by McDonnell Douglas Corporation. Called payload assist modules (PAMs), these upper stages are offered in two sizes: PAM-D for smaller spacecraft and PAM-A for larger ones. PAM-D flew six commercial missions during 1982 as the third stage of the Delta expendable launch vehicle. To be used for flights on the Space Transportation System, PAM-D completed qualification and verification tests during 1982. It launched the Satellite Business Systems' *SBS 3* and Telesat Canada's *Anik C-3* from the Shuttle's cargo bay during the November STS 5 flight, sending them into geosynchronous orbit for communications satellite operations. PAM-A qualification and production activities were halted during 1982, pending definition of spacecraft needs and launch schedules.

Advanced Planning

NASA investigated systems that could expand the Space Transportation System toward a permanent presence in space. Studies included innovative concepts to provide more economical payload support, to build and repair in space, to operate long-duration manned facilities, and to provide more economical transportation.

Design-definition (phase B) studies and advanced development of free-flying, unmanned, low-earth-orbit platforms, to be deployed and serviced by the Shuttle orbiter, were completed. Other achievements during 1982 included advanced development and a firm price offer for an innovative Tethered Satellite System (TSS), preparatory to a proposed program to start in fiscal 1984. The program is planned as a cooperative undertaking with the government of Italy, which would develop a spacecraft for TSS. JSC completed competitive preliminary-concept studies of satellite service systems that would be supplied by contracts with Lockheed and Grumman. The three-phase studies investigated requirements, concepts, and system economics. The results were made available to all interested NASA and DoD elements. In June 1982, some 350 DoD and civilian participants attended a satellite services workshop at JSC, for discussions of servicing equipment, operations, and economics; satellite design; berthing and docking; and fluid transfer.

MSFC completed preliminary system-concept studies of a teleoperator maneuvering system (TMS), essentially a remotely piloted, mini-tug, orbital service vehicle. The TMS is planned to have phased capabilities for orbital placement, retrieval, maintenance and repair, and space debris control.

Operation of the Space Transportation System

The November inauguration of Space Transportation System operations with two commercial satellites—the upper-stage Delta-class payloads *Anik C-3* Canadian communications satellite and *SBS 3* U.S. communications satellite—was particularly fitting because some 60 similar payloads are planned to be launched in the first five years of operations. Other missions in the planned use of the Space Shuttle include 16 DoD-dedicated missions, plus reservations for 13 additional DoD payloads sharing the Space Shuttle flight with other users. In addition, more than 40 NASA payloads are planned for launch in the same five years. The outlook for Space Shuttle launches through 1987 is for a variety of payloads and users, confirming the flexibility and accommodation potential of the new STS for all customers.

NASA signed launch service agreements with 10 users: INTELSAT, Satellite Business Systems, the governments of India and Indonesia, the West German corporation Messerschmitt-Boelkow-Blohm GmbH, Telesat Canada, the German Federal Ministry for Research and Technology for the German D-1 Spacelab mission, Space Communications Co. for the Tracking and Data Relay Satellite, the government of Mexico, and the Arab Satellite Communications Organization. Negotiations were continuing with 14 other users at the end of the year.

Operations Capability Development. Among planned improvements to operational capability from 1983 through 1988 are servicing equipment and techniques for Shuttle-compatible payloads such as the *Space Telescope* and other low-earth-orbit spacecraft.

In 1982 NASA received approval to develop payload servicing components for a Space Shuttle mission to repair the partially disabled *Solar Maximum Mission* observatory now in earth orbit. Preparing to repair the spacecraft in 1984 will also provide generic hardware and software components for future servicing missions. Included are the manned maneuvering unit (MMU) to permit astronauts to work at some distance from the Space Shuttle orbiter; the manipulator foot restraint (MFR) to provide a mobile astronaut work station at the end of the remote manipulator system's rendezvous radar, with associated software for the orbiter; direct-ascent launch techniques to achieve Shuttle orbits significantly above the 300-kilometer standard orbit; and a set of astronaut tools qualified for use in space. The Solar Maximum Repair Mission will demonstrate each of these components while restoring the spacecraft to full operation.

Policies and Procedures. Refinement of policies governing use of the Space Transportation System continued throughout 1982. Final principles for reimbursement of Spacelab services were applied to the launch service agreement negotiated with the Federal Republic of Germany for the D-1 mission. A reimbursement policy for the use of lockers in the orbiter's mid-deck was drafted. A revision of the basic Shuttle policy was developed to comply with new pricing principles selected for the second three years of STS operations. And studies and analyses were made to assist development of offers for retrieval services for launches from the Eastern Test Range (ETR).

The cargo price for Shuttle flights during the second three years of operations (1986-1988) was set at $38 million (1975 dollars, subject to escalation). This price includes a reflight premium; no use fee will be added. The new price is based on the three-year average out-of-pocket cost to launch (the annual average costs of consumables plus the additive costs for launch and flight support for commercial and foreign launches). The goal of this pricing policy is to return to full cost recovery annually after 1988. The $38-million (1975 dollars) price is an 85 percent increase over the 1982-1985 price of $18.3 million and its added use fee of $4.3 million (current year dollars). The new price remains competitive with prices for alternate forms of space transportation.

Spacelab

The Spacelab program, a joint NASA and European Space Agency (ESA) endeavor, achieved several significant milestones in 1982. ESA delivered the Spacelab module, which will be used as a shirtsleeves laboratory on selected Shuttle missions, to NASA at the Kennedy Space Center (KSC) in December 1981. Vice President Bush attended a ceremony marking the event in February 1982. In July, NASA received the second delivery of Spacelab flight hardware, consisting of three pallets for mounting scientific instruments that must be exposed to space and an "igloo" (a container housing the electronics necessary to operate the pallet instruments). Except for a precision instrument-pointing system (IPS), this latest delivery basically completed ESA's commitment made in the 1973 intergovernmental agreement and the memorandum of understanding on hardware deliveries.

In March 1982, NASA flew its second complement of scientific experiments aboard the Space Shuttle. Instruments on the OSS 1 pallet measured the physical environment around the orbiter and used Spacelab equipment for science observations. This STS 3 flight marked the second successful flight of Spacelab equipment in space, the first having been OSTA 1 on STS 2 in 1981 (see "Resource Observations," above).

In Europe in August, the critical design review for the instrument-pointing system essentially completed the IPS design phase. Late in 1982, McDonnell Douglas Corporation shipped the crew transfer tunnel to KSC. It will connect the Spacelab module to the orbiter cabin.

The first all-up Spacelab module mission, requiring a dedicated Shuttle flight, is planned for the latter part of 1983. A cargo integration review for the mission was completed in June 1982. Integration of the experiments and all verification flight instrumentation into Spacelab will begin early in 1983 at KSC. Training of astronaut mission specialists and European and American payload specialist candidates for this joint mission continued throughout 1982.

NASA, responsible for operating Spacelab, is developing a number of unique facilities, including a Spacelab payload operations control center (POCC) at the Johnson Space Center in Houston. Experimenters at the POCC will review experiment results as they occur and converse with the orbiting payload specialists. Integration and testing of the POCC in the overall Space Shuttle mission control complex began in 1982, with a goal of becoming operational in mid-1983. During the year, NASA and the U.S. Air Force signed an agreement on use of Spacelab equipment for future DoD experiments.

Expendable Launch Vehicles

NASA launched nine missions on nine expendable launch vehicles in 1982, using seven Deltas and two Atlas-Centaurs. Of the nine, eight were reimbursable launches for other agencies or commercial customers and one was a NASA applications mission. NASA's expendable launch vehicle family consists of the all-solid-fueled Scout, the Delta, the Atlas-E/F, and the Atlas-Centaur. No missions were scheduled for launch on Scout or Atlas-F during 1982, but launches on both vehicles are scheduled for 1983 and subsequent years.

The most often used launch vehicle, Delta, supported six commercial and international communications missions, for which NASA was fully reimbursed: *RCA-Satcom 4* and *5*, Western Union's *Westar 4* and *5*, India's *Insat 1A,* and Canada's *Anik D.* In addition, it launched *Landsat 4* for NASA. Improved, more powerful Deltas were used for the Landsat and *Anik D* launches. An Aerojet engine and a larger-diameter tank increased the Delta weight-carrying capability by 140 kilograms into geostationary-transfer orbit.

Atlas-Centaur, NASA's largest expendable vehicle, launched two communications satellites for the INTELSAT organization. This vehicle will be used at least until 1987 to launch additional satellites for INTELSAT and for DoD FLTSATCOM communications missions.

Space Research and Technology

The NASA space research and technology program provides the advanced technology base for making possible and improving operational capability, reliability, and affordability of existing and planned space systems for NASA, commercial, and military applications. The program includes the key discipline and systems research in chemical propulsion, computer science and electronics, space data and communications, materials and structures, space energy conversion, and aerothermodynamics. It includes significant in-space testing and experimenting. NASA technology also supports energy research and applications by the Department of Energy and other agencies.

Research and Technology Programs

Chemical Propulsion. Technology for advanced reusable earth-to-orbit propulsion focused in 1982 on extending component life and thus extending maintenance intervals. Cooling turbine blades with hydrogen fuel proved inadequate because high heat-transfer rates were generated by the high-pressure, hydrogen-rich, turbine-drive-gas environment. Alternate cooling techniques tailored specifically to rocket engines are being analytically evaluated.

Rusable orbital-transfer propulsion technology continued to be directed toward an advanced, high-performance, expander-cycle engine, considered critical to the development of an advanced upper-stage vehicle. Conceptual designs have been developed that permit high-pressure, high-expansion-ratio operations leading to very high performance over a wide throttling range. The critical technology is associated with combustor designs permitting very efficient heat transfer through the combustor wall into the working fluid used both for regenerative cooling of the combustion chamber and for turbine gas. A number of advanced combustor concepts are being studied analytically before hardware testing.

Computer Science and Electronics. Industry is making rapid advances in supercomputer technology, human-computer interfaces, and artificial intelligence. In recognition of the significance to space programs, NASA established a new activity in computer science to adapt this technology to aerospace applications, to advance computing technology where NASA requirements push the state of the art, and to provide advanced computational facilities for aerospace research. A major commitment is the establishment of an independent Research Institute for Advanced Computer Science (RIACS), to be operated at the Ames Research Center by the Universities Space Research Association.

A significant advance in multifunction, microwave technology was the development of the prototype pushbroom microwave radiometer. This multiple-beam radiometer uses a precision noise-injection modulation technique, a microwave integrated-circuit front end, and advanced digital-signal processing. The development will provide technology for future radiometric missions requiring simultaneous remote measurements over large areas of the earth. Such missions include determination of ocean salinity and soil moisture. The radiometer will be flown in the 1983 AgRISTARS flight-test program.

Low-temperature operation of semiconductors provides the potential for very low signal loss and, therefore, substantially lower internally generated noise in integrated systems. Several superconducting tunneljunction devices were fabricated and operationally validated during 1982. These devices have the potential of significantly improving the low-noise characteristics of receivers for both intersatellite and earth-to-space communications.

Space Data and Communications. The first 60-gigahertz, low-noise receiver was developed for spacecraft systems' data transfer. Development of a solid-state, 60-Ghz power amplifier was also completed. These capabilities will permit high transfer rates of large quantities of data in millimeter-wave, intersatellite communication links. Such links are an important characteristic of an advanced, fully integrated ground-to-space communication system.

Materials and Structures. Laboratory tests demonstrated that a new, low-cost material can increase life and durability of the Space Shuttle orbiter's thermal-protection shield. The advanced, flexible, reusable surface insulation (AFRSI) is a quiltlike sandwich formed with silica on the outside and microquartz felt in the middle. The layers, sewn together in the middle to form a series of one-inch squares, will be used in temperature ranges below 650°C. The use of AFRSI on the lee side of the orbiter offers more tolerance to damage, easier maintenance, and lower installation cost than the tiles it replaces.

The use of the Space Shuttle as a low-cost, routine transportation system requires more systematic, accurate, and cost-effective prediction of loads. Advanced analytical techniques for predicting the Shuttle cargo bay's vibroacoustic environment and payload dynamic response were developed and validated using recorded flight data. New methods for analyzing dynamic loads reduced the time required for a complete cycle analysis of a Shuttle payload from nine months to less than one month.

Space Energy Conversion. Significant improvements in the power per kilogram, the cost, and the efficiency of solar-array power systems have been achieved. A method of growing gallium-arsenide cells and then transferring the resulting films to thin, low-cost, glass substrates yielded 460 watts per kilogram—a sevenfold improvement over the best flight cell in use. In the area of low-cost solar arrays, a miniature Cassegrain concentrator with a concentration ratio of 100 has been designed, fabricated, and tested. Because the array features cells less than a centimeter in diameter and concentrators that can be fabricated like flash cubes, it has the potential for reducing array costs to about $30 per watt, or one-twentieth of current costs. Concepts also were identified that could potentially revolutionize solar-cell energy conversion, increasing efficiencies from the present 16 percent to as much as 50 percent. These concepts include coupling sunlight into the electronic surface-charge density, cascading solar-cell junctions for selective spectral use, and exploiting the unique properties of the photoactive protein rhodopsin.

Intensive work continued in high-capacity energy storage critical to long-duration missions. The breadboard model of a solid-polymer-electrolyte, fuel-cell-electrolysis system is being extensively tested. An alternate energy storage system based on the electrochemistry of nickel and hydrogen has demonstrated an efficiency of 82 percent over 100 simulated, low-earth-orbit, day-night cycles. This technology could reduce the weight of energy storage systems by one-half.

Aerothermodynamics. Preliminary data from flight-instrumentation and orbiter experiments on the first flights of the Space Shuttle confirm the value of the simulation at aeronautics and space ground-test facilities used in the orbiter design and development. The predictability of the ascent and descent performance of each Shuttle flight demonstrated the validity of the aerodynamic and aerothermodynamic design data base, developed by both experimental and numerical techniques. Measurements obtained from the orbiter experiments on tile-gap heating provided information used in improving performance and extending reusability of the thermal protection system.

Shuttle Flight-Test Results

Extending technology development into space by flight tests aboard the Shuttle orbiter in 1982 accelerated advanced space R&D. Some experiments measured characteristics and performance of the Shuttle itself to discover principles applicable to future advanced transportation. The orbiter provides a far greater range of test parameters than either ground facilities or experimental aircraft.

Flight data indicated that the thermal protection system's performance margin provides the Shuttle with a greater cross-range capability than planned and increased confidence in its use under less rigorous maintenance conditions. Measurement of various aerodynamic coefficients provided research-quality data for improving the theoretical and ground-based experimental methods of analyzing aerodynamic force and control.

Additionally, the value of the Shuttle as a platform for technology flight experiments was demonstrated during 1982. An experiment to develop discrimination and classification of image data on board a spacecraft demonstrated the principle and defined a system concept. A flight test of technology to provide thermal isolation of sensitive astronomy instruments permitted relaxation of thermal control requirements.

NASA Energy Programs

NASA supports the Department of Energy (DOE) and other agencies by applying aerospace expertise to the development of energy technology. This activity encompasses a range of projects in solar and fossil energy and in energy conservation—important examples of which are cited below. Progress was made during 1982 in automotive propulsion research, wind-energy technology, terrestrial photovoltaic-array technology, solar thermal-energy conversion, and international applications of solar energy.

Automotive Propulsion Research. NASA continued its support of DOE's vehicle and engine R&D programs by developing technology for gas turbines, the Stirling engine, and electric and hybrid vehicles. The Stirling engine project, conducted by the team of Mechanical Technology, Inc., and United Stirling of Sweden, has accumulated more than 1300 hours of steady-state and transient testing of experimental engines with efficiencies equal to that of automotive diesel engines and with emissions less than Environmental Protection Agency research goals.

Research on the ceramic components to meet the 1290°C to 1370°C operating temperature of an advanced, automotive, gas turbine engine continued at the Detroit Diesel Allison Company and the Garrett Corporation. Cold spin tests of simulated and actual turbine rotors have demonstrated that ceramic materials can achieve the required strength.

Research on propulsion technology for electric vehicles emphasized both alternating-current (AC) and direct-current (DC) systems. During 1982, development of electronically commutated, permanent-magnet, propulsion motors was completed at AiResearch and Virginia Tech. At one-fifth to one-half the weight of conventional motors, the permanent-magnet motors for DC have demonstrated a combined motor and controller efficiency of 90 percent. A contract was awarded to Ford Motor Company to develop technology for an advanced AC electric powertrain. The powertrain will consist of a concentric AC motor, automatic transaxle, and differential integrated into a single, lightweight unit. General Electric Company, Ford's principal subcontractor, will develop the motor, inverter, and motor controller from technology developed under an earlier contract.

Wind-Energy Technology. Operation of the wind turbine "farm" consisting of three Mod-2, 2500-kilowatt wind turbines continued at Goodnoe Hills, Washington, under the direction of NASA and DOE. Each of the three machines, built by the Boeing Engineering and Construction Company, surpassed 1000 hours of operation during 1982. The test program provides valuable data on interactions among the three machines as well as basic information on wind turbine operations.

The world's most powerful wind turbine, the WTS-4, began operation during 1982 near Medicine Bow, Wyoming. This 4000-kW turbine, with its 78-meter (tip-to-tip) blade on an 80-meter-high tower, was developed under NASA technical direction by the Hamilton Standard Division of United Technologies Corporation. The Department of Interior sponsored this project as well as the construction of a 2500-kW, Mod-2 wind turbine at the same site. Mod-2 has a 92-meter blade and a tower 61 meters high. Data from the two wind turbines will be evaluated over two years as part of the consideration of a "wind farm" of up to 40 machines that may be erected in Medicine Bow.

Testing was completed on the four intermediate-size (200 kW) wind turbines to advance the development of more efficient second-generation machines (Mod-2) and WTS-4) and contributed to definition of the third-generation, 7000-kilowatt, Mod-5 design.

Terrestrial Photovoltaic-Array Technology. Research directed toward cost-competitive, long-life photovoltaic arrays made progress in silicon refinement processes, silicon-sheet growth techniques, environmental isolation materials, cell and module processing techniques, and advanced module-array designs. Continuing transfer of technology advances to industry has led to establishment of manufacturing processes, and economic analyses indicate that price goals of 70 cents per peak watt (1980 dollars) will be feasible if private industry makes the required investments.

Solar Thermal-Energy Conversion. Solar concentrator dishes combined with heat engines have been tested since 1979 at Edwards, California. Tests to date have used an experimental 11-meter-diameter dish to focus solar radiation onto a high-temperature receiver. In 1982, a Stirling engine placed at the focus of the experimental parabolic dish demonstrated an overall efficiency (sunlight-to-electricity) of 29 percent—a milestone for solar conversion systems.

International Applications of Solar Energy. NASA supports DOE by providing standardized solar-cell power systems for health service, water, educational needs, and public lighting for four villages in Gabon, Africa. A contract for the four systems was awarded in late 1982, with installation in Gabon scheduled for late 1983. Solar-cell-powered refrigerator-freezers, jointly funded by DOE and the Center for Disease Control for cold storage of vaccines in remote medical posts, were installed in the Maldive Islands, Gambia, Ivory Coast, Colombia, and Peru. NASA continued technical support to the Agency for International Development (AID) for solar energy-related projects in many other countries in South and Central America, Southeast Asia, and Africa.

Space Tracking and Data Systems

NASA's space tracking and data systems provide tracking, command, telemetry, and data-acquisition for earth-orbital science and applications missions, planetary missions, sounding rockets, research aircraft, and the Space Shuttle program. Two worldwide tracking networks, one for deep-space and one for earth-orbital missions, provide this support. In addition, on-site tracking and data-gathering systems support the aeronautical research and sounding rocket programs. A global communications system links tracking sites, control centers, and data processing facilities, providing real-time data processing for mission control and determination of orbit and attitude, as well as routine data processing for applications and scientific missions.

Network Operations

The Spaceflight Tracking and Data Network (STDN) supported 41 missions in 1982, including the newly launched *Landsat 4*. The work load includes NASA missions as well as launch and on-orbit support to missions of foreign countries and commercial firms on a reimbursable, noninterference basis. This network also supports Space Shuttle missions, covering STS 3, 4, and 5 flights in 1982. A temporary tracking station at White Sands, New Mexico, supported the STS 3 landing.

An agreement with the government of Senegal permitted upgrading the Dakar UHF air-to-ground voice station to an S-band-telemetry, voice-and-command station before the STS 4 mission. Without this change at Dakar, there would have been a major gap in telemetry data coverage between Bermuda and Hawaii for all due-east launches from STS 4 on. This mid-point station permits analysis of initial orbital-maneuvering-system burn data and provides for crew updates in the event of an abort.

Closure of the Quito, Ecuador, station was completed during the year. After removal of needed equipment, the station was turned over to the government of Ecuador, which may use it as a Landsat station in the future.

During 1982, the Deep Space Network (DSN) tracked 11 space probes, 4 of them at distances of more than 1 billion kilometers from the earth. The DSN now has one 64-meter and one 34-meter antenna at each of three stations: Goldstone, California; Madrid, Spain; and Canberra, Australia. During 1982, preparation was begun to add another 34-meter antenna at two of the deep-space complexes. The new antennas, when completed in 1985, will enhance network sensitivity for the *Voyager 2* encounter with the planet Uranus in January 1986. During such planetary encounters, all deep space antennas at a single complex are focused on the spacecraft, and all signals received are electronically combined, giving the effect of one large "super antenna" with sufficient gain to receive imaging data sent from the ends of the solar system.

Control Centers and Data Processing

Five control centers monitor, command, and control some 20 spacecraft. A new control center is also being prepared for the *Space Telescope*.

Processing bulk science data from spacecraft is another important function. Traditionally, receipt, capture, accounting, and product generation have been classified broadly into two major categories: image and telemetry (non-image) data processing. The Image Processing Facility converts data from spacecraft measurements of earth features or phenomena into pictures of their digital representation on computer tapes. Telemetry data processing separates the science data for the individual investigators and records the data on experimenter tapes. Also, plots or histograms may be produced. A major subactivity in the future will be processing data from Spacelab missions by the Spacelab Data Processing Facility, which is being built. The facility will support the first Spacelab mission, scheduled for launch in late 1983.

Tracking and Data Relay Satellite System (TDRSS)

The first satellite of the new Tracking and Data Relay Satellite System was in the final stages of testing and preparations for launch. The satellite was to be launched in 1983 into low earth orbit by the Space Shuttle and then boosted into synchronous orbit by an Air Force inertial upper stage. The prime contractor, Space Communications Company (Spacecom), is the owner and operator of the system, contracting with NASA to provide 10 years of service, with responsibility for design, development, integration, operation, and maintenance.

The system for NASA use, when complete, will consist of three synchronous-orbit satellites, including one spare; it will relay commands to and data from the Space Shuttle and other earth-orbiting spacecraft to a ground terminal at White Sands. Other major NASA components, in conjunction with TDRSS, will constitute the Space Network, including the Network Control Center (NCC) at Goddard Space Flight Center in Greenbelt, Maryland. When TDRSS becomes fully operational in 1984, many ground tracking stations, no longer required, will be closed. TDRSS and the Space Network will provide greater versatility and operational effectiveness for the Space Shuttle, *Space Telescope,* and NOAA's operational Landsat satellites.

Aeronautical Research and Technology

NASA's aeronautical research and technology program provides the advanced technology base for superior U.S. aircraft—improving speed, range, comfort, and safety at reduced direct operating costs. The program includes maintaining a strong base in the technological disciplines, investigating advanced technology at the component or system level to establish the utility of proposed advanced development, supporting the military in development and demonstration of superior military systems, and supporting the Federal Aviation Administration with complementary research in aircraft safety.

During 1982, NASA completed two major U.S. wind tunnels—the National Transonic Facility at

Langley Research Center, Hampton, Virginia, and the 80- by 120-foot Low-Speed Facility at Ames Research Center, Moffett Field, California. The Langley facility provides the most advanced transonic test capability in the world. Its 8- by 8-foot test section permits nearly exact simulation of flight conditions of the world's largest aircraft at near-sonic flight speeds and realistic altitudes. The Ames wind tunnel will provide the nation new and needed capability for testing full-sized rotorcraft and V/STOL aircraft by using a straight-through flow passage that eliminates exhaust contamination in the test medium. A set of turning vanes failed during a December test and checkout run, causing major damage to the facility's drive fans. Plans for repair and returning the facility to operation were under way.

Maintaining a Strong Technology Base

NASA's disciplinary aeronautical research includes fluid and thermal physics, materials and structures, controls, and human factors.

Fluid and Thermal Physics. The ability to compute the aerodynamic forces and torques acting on aircraft was substantially advanced during 1982. Scientific computers permitted predictions with good accuracy of transonic flows over wings, bodies, and nacelles, facilitating economical study of the best positioning of these basic aircraft components. For some specialized conditions, flow computations have become sufficiently accurate to shorten substantially the wind-tunnel testing of airfoil designs. An advanced three-dimensional panel code recently completed can model separated rolled-up vortex wakes for estimating forces acting on wings with variable leading-edge sweepback.

Materials and Structures. In the national undertaking to decrease reliance on rare imported materials, NASA studied the role of cobalt in high-temperature nickel-base superalloys for gas-turbine engines. Research has shown that decreases in cobalt level do not change alloy strength, but do lower resistance to high-temperature creep. Understanding the mechanisms responsible should lead to development of suitable substitute elements to maintain high-temperature properties.

In structural analysis and aeroelasticity, research established technology for understanding the buckling and nonlinear response of composite aerospace structures and for methods of suppressing active and passive flutter and alleviating loads on aerospace vehicles. Techniques for analyzing flat, stiffened, composite panels with postbuckling response were developed and gave excellent correlation with test results, permitting more efficient application of composites to aerospace structures. Wind-tunnel tests demonstrated for the first time an adaptive system for suppressing flutter in fighter aircraft whose configuration changes suddenly with the release of stores. The system was validated by ejecting a wing-tip missile in a wind-tunnel flow condition above the flutter boundary for the wing without the missile.

Controls and Human Factors. A pioneering effort in fault-tolerant-system technology reached a significant milestone in 1982 with the delivery to NASA of engineering models of two computer concepts for evaluation. The fault-tolerant multiprocessor (FTMP) and software-implemental fault-tolerance (SIFT) computers have been designed for highly reliable, failure-free operation in future aircraft flight control systems. The engineering models were fabricated using standard, commercial aircraft electronic computers and other components. A year of testing has proved the basic operation of the FTMP. A mathematical proof of SIFT verified its fault-tolerant features. When fully developed, this technology will provide nearly failure-free, low-maintenance electronic systems that will permit the design of a new generation of aircraft in which aerodynamic stability and structural integrity are totally dependent on the electronic flight control system. These new aircraft will be more fuel-efficient and more readily available for missions.

Systems Research for Future Applications

Advanced Turboprops. Analytical and experimental efforts over the past several years have produced a preliminary design for a large-scale research propeller. During 1982, work began toward fabrication and ground test of 2.7- to 3-meter-diameter propeller assemblies. Experimental programs in acoustics and installation aerodynamics developed data bases confirming that advanced turboprops would use 15 to 20 percent less fuel than advanced turbofans would. Near- and far-field noise measurements of propellers, using the JetStar aircraft, were completed, and fuselage noise-attenuation tests in an anechoic chamber provided data on several promising wall-treatment concepts. Wind-tunnel tests of turboprop wing installations with contour changes to accommodate the swirling slipstream gave encouraging results.

Energy-Efficient Engines. Operation of components integrated into a research test-stand engine—over a full range of speeds, pressures, and temperatures—demonstrated the advanced component technology in an engine environment. Integrated component performance and engine starting and transient capabilities were excellent. The technology developed can reduce fuel consumption by advanced turbofan engines as much as 15 percent.

Laminar Flow Control. Reduced drag and increased efficiency of long-range transport aircraft requires maintenance of laminar flow over the wing and tail surfaces. Removing through a surface suction system small amounts of air from the boundary layer can maintain this flow, with the suction levels dependent on airfoil characteristics. NASA has designed and fabricated an advanced, swept, supercritical airfoil with performance comparable to that of advanced turbulent airfoils and with features that will simplify laminarization. Verification of performance by wind-tunnel testing began in early 1982. Both slotted- and porous-surface systems will be evaluated. Results will provide basic data for designing suction systems and also for validating improved design methods. Flight tests beginning in 1983 will give operational experience with wing leading-edge systems.

Rotorcraft. NASA's rotor systems research aircraft (RSRA) completed its first flight research phase, which measured rotor and fuselage aerodynamic loads in hover and low-speed forward flight with its unique measurement system. The two tilt-rotor research aircraft continued proof-of-concept flights and extensive operational demonstration flights for the military services, including Navy sea trials based on the U.S.S. *Tripoli*. A highly instrumented AH-1 helicopter flown in another research program simultaneously measured rotor aerodynamic loads and external noise signatures to provide a data base for developing noise prediction methodology.

Tests completed on the aft transmission of an XCH-62 heavy-lift helicopter provided data for correlation with an improved analytical method of predicting loads on large, spiral, bevel gears. Testing on the CH-47 airframe obtained vibration data for correlation with analytical methods. A number of advances were made in computational fluid-dynamic methods to account for the influence of unsteady motion, vortex interaction, and transonic flow on rotor aerodynamics.

Powered Lift. Design studies completed for a single-engine, supersonic short-takeoff and vertical-landing (STOVL) fighter-attack aircraft revealed several promising concepts that will be investigated in wind-tunnel testing. One concept employs remote burning of the engine-fan air stream for thrust and lift; another uses additional mass air flow provided by an ejector to supply thrust for vertical operation.

Results from model tests of a twin-engine V/STOL fighter with flow-through nacelles are being compared with analytical predictions. Future testing will use new, advanced-propulsion simulators now being checked out. The simulators are miniature propulsion systems that will permit more accurate wind-tunnel evaluations of an aircraft concept than has been possible before.

Supersonic Cruise Technology. Supersonic-cruise research in 1982 was directed toward completing selected projects from the terminated supersonic-cruise research program and initiating technology programs for military aircraft. Analysis and mathematical modeling of the structural-response dynamics of large flexible aircraft at supersonic speeds were published, completing a 10-year effort that began with flight tests of the B-70 and ended with the B-1. Fabrication of four configurations of variable-geometry, axisymmetric inlets for use on future transports was completed in the spring of 1982. These inlets were tested in the 9- by 15-foot tunnel at Lewis Research Center to provide the world's only data base on the relationship of fan noise suppression and aerodynamic performance of axisymmetric supersonic inlets.

Two analyses of advanced technologies applicable to military supersonic cruise aircraft sought to identify high payoff in longer range and larger payloads. Technologies include arrow-wing concepts and wing-fuselage blending, advanced aluminum and composite structures, improved propulsion system components and controls, and integration of low-drag conformal weapon concepts. General Dynamics this year made the first application of the NASA-developed arrow wing to two F-16XL aircraft that were completed in July and September and are now being flight-tested at Edwards Air Force Base.

Technical Support for the Military

X-29 Forward-Swept-Wing Flight Demonstrator. NASA is supporting development of the X-29A funded by the Defense Advanced Research Projects Agency, assisting preparation for the first flights, scheduled for 1984, and preparing to conduct later government flight tests. During 1982, wind-tunnel tests at Ames and Langley Research Centers obtained low- and high-speed aerodynamic data and investigated inlet performance. Technical support was also given in instrumentation, structural dynamics, handling qualities, and control systems.

Advanced Fighter Technology Integration (AFTI). The Air Force and NASA cooperate in two AFTI programs for future fighter applications. The AFTI/F-16 incorporates an advanced, digital, fly-by-wire control system and canard surfaces for direct force control. During 1982, General Dynamics, Fort Worth Division, completed modifications of the F-16 aircraft to include digital flight controls. The aircraft made its first flight on 10 July, and the joint flight research program will continue at NASA's Dryden Flight Research Facility during 1983.

The mission-adaptive wing (MAW) of the AFTI/F-111 will demonstrate the aerodynamic performance improvements of a smooth, variable-camber airfoil on that aircraft. A supercritical wing design has been developed that permits great variability in wing camber, using smooth leading- and trailing-edge devices to let the airfoil assume many shapes for optimum performance over a wide operating envelope. During 1982, the Boeing Aerospace Company has been modifying the F-111 aircraft wings with the variable-camber system. In 1983 the wings will be delivered to Dryden for installation and checkout. Flight research is scheduled to begin in the summer of 1983.

Improving Aircraft Safety

In cooperation with the Federal Aviation Administration, NASA completed development of the aviation-safety reporting system (ASRS), a program for collecting human factors data on aircraft crew performance. ASRS is a voluntary, confidential, nonpunitive, crew reporting system designed to surface deficiencies in national aviation before accidents occur; it is strongly supported by the aviation community. The President's Task Force on Aircraft Crew Complement made extensive use of ASRS data in its review, and it has proved a valuable tool in planning research programs in aviation safety. Managed by NASA for the FAA, it has received more than 30 000 reports since 19 April 1976, issued 740 alert bulletins, and published 240 reports. FAA requested that NASA extend its management through 1987.

Work to define atmospheric hazards and advance fire and crash safety technology made progress in 1982. The accumulation of data from 147 direct lightning strikes on the F-106B research aircraft contributed a major advance in characterization of atmospheric lighting. NASA participated in an interagency field research program that collected data during more than 50 wind-shear episodes at Denver to define the fine-scale nature of this hazard. A flight research program began to compare natural icing conditions with research data developed in the icing research tunnel at Lewis Research Center.

Also with FAA, NASA continued developing advanced fireworthy lightweight materials to reduce the threat of fire in aircraft cabins. Specifically, new seat-cushion foams were developed and tested. NASA and FAA began a joint safety-research program to demonstrate antimisting-kerosene safety fuel, measure structural loads, and evaluate advanced metallic and composite crashworthy structures, in a remotely controlled crash of a civil jet transport scheduled for 1984. Close cooperation with FAA continued in icing, lightning, and aircraft landing-gear research.

Department of Defense

To maintain the security of the United States, the Department of Defense acquires and operates space and aeronautical systems and pursues advances in related research and technology development. Cooperation with NASA and other federal agencies produces civil benefits. During 1982, Department of Defense space systems received a new focus. The secretary of defense on 22 June 1982 approved a statement of policy to guide activities in furtherance of the national space policy announced by the president on 4 July 1982 (see appendix F). This DoD policy supports the principles underlying the United States space program and directs the continued maintenance of a strong technology base, with leadership in areas necessary for effective national security. The policy recognizes that, since space systems can effectively support military missions in both peace and conflict, future military use of space—including command and control, communications, navigation, environmental monitoring, warning, surveillance, and space defense—should have an operational orientation.

Soviet development of an operational antisatellite (ASAT) capability presents the potential for space to become a hostile environment. Therefore, DoD space policy directs that military space systems, including essential ground elements as well as orbiting spacecraft, be designed, developed, and operated to enhance the ability of critical mission functions to survive.

Space launch is critical to any space capability, and the policy requires an adequate launch capability for flexible, responsive access to space to meet national security needs. DoD recognizes the Space Shuttle as the primary space launch system and the need for continued cooperation with NASA to develop a fully operational Space Transportation System.

In a separate but related action, the Air Force consolidated its management of space activities, forming a new major command, Space Command, on 1 September 1982. Headquartered in Colorado Springs, Space Command will be built around the existing Aerospace Defense Center staff. The Air Force also established within the Air Force Systems Command (AFSC) a Space Technology Center at Kirtland Air Force Base, New Mexico, in October. Under this realignment, three AFSC laboratories—the Air Force Rocket Propulsion Laboratory, the Air Force Geophysics Laboratory, and the Air Force Weapons Laboratory—will constitute the elements of the Space Technology Center under the Air Force Space Division. The center will focus on the major scientific disciplines for launch vehicle and spacecraft technology.

Space Activities

Military Satellite Communications

In 1982, DoD continued to operate a range of first-generation military satellite communications (MILSATCOM) systems for support of worldwide military forces and began to develop and deploy second-generation MILSATCOM systems. The systems support three main user communities: (1) command and support forces of the commanders in chief and the military services and agencies, (2) strategic and tactical nuclear forces, and (3) strategic and tactical conventional forces. DoD also continued to lease selected commercial satellite communication (COMSATCOM) circuits and began to investigate approaches with private industry for ensuring that systems can survive in periods of national emergency to augment DoD systems.

Defense Satellite Communications System (DSCS). For communication needs of the command and support forces, DSCS Phase II provides high-data-rate communications to the Department of Defense, Department of State, and allied nations. The system operates at the superhigh-frequency (SHF) 8- to 7-gigahertz band, with fixed and large, transportable ground terminals distributed around the globe. Major improvements in the operational system began with the October 1982 launch of the first of a new generation of communications satellites—the DSCS III series. The DSCS III system also operates in the SHF band, but features increased antijamming and other protection. The DSCS III satellite was paired with a DSCS II satellite and launched atop the first Titan III(34)D launch vehicle with the new inertial upper stage. At year end, the DSCS III satellite was undergoing in-orbit evaluation.

Air Force Satellite Communications System (AFSATCOM). For the nuclear-capable forces, the Air Force operated the ultrahigh-frequency (UHF)

AFSATCOM space segment, made up of packages on the Satellite Data System (SDS), the Fleet Satellite Communications System (FLTSATCOM), and other host satellites. The Air Force, and to less extent other DoD users, continued to field AFSATCOM terminals. At the conclusion of the year, about 450 of the projected 600 UHF terminals were in operational service.

Fleet Satellite Communications System. The FLTSATCOM system provides moderate-capacity mobile-user service in a worldwide communications system. It supports the most urgent tactical-peacetime and mixed-management communications requirements of the Navy and commanders in chief of the unified and specified commands, as well as communications requirements of the strategic forces. The four FLTSATCOM satellites provide virtually worldwide service with an aggregate of more than 13 spacecraft years of service. *FLTSATCOM 1* will reach the five-year point in February 1983. The Navy has begun long-lead material procurement for three additional FLTSATCOM satellites to extend these services. Fabrication of the Navy's leased satellite (LEASAT) is well under way for Space Shuttle launches scheduled for 1984, to fill continuing Department of Defense communications requirements. FLTSATCOM capacity is supplemented by lease of UHF transponders on commercial Marisat satellites. The Navy, major user of this capability, had deployed about two-thirds of its UHF terminals by the end of 1982. Terminals are expected to total about 1700 when deployments are completed.

Army Satellite Communications Activities. The Army develops and procures ground terminals for satellite communications for all the military departments. DSCS provides high-data-rate interconnection, and Ground Mobile Forces Tactical Satellite Communications (GMF-TACSATCOM) provides communications for tactical forces. The Army also conducts research to advance satellite terminal technology.

New Satellite Communications Initiatives. Emphasis continued on survivability and endurance of satellite communications. DoD began concept validation studies to define a system to serve the strategic and tactical forces (nuclear and nonnuclear) of all three services. The studies concluded with a September 1982 request for proposals for engineering development of the MILSTAR satellite. Contract award is scheduled for the spring of 1983. This system, operating in the 44- and 20-GHz bands, will permit worldwide, jam-resistant communications to satisfy the minimum essential needs for commanding and controlling strategic and tactical forces. Initially, a scaled-down version of the MILSTAR capability will be tested on a FLTSATCOM satellite. The Massachusetts Institute of Technology's Lincoln Laboratories began developing this limited capability, and the services are developing terminals to provide an operating capability in the late 1980s. The extremely-high-frequency (EHF) SATCOM terminal entered full-scale development for future use with the MILSTAR satellite. The Navy is the lead service in coordinating terminal development and production to ensure future interoperability, commonality, and coordinated logistics and technology development among the services. The EHF package to be developed by Lincoln Laboratories for deployment aboard one or more FLTSATCOM satellites will support operational evaluation of the terminals in time for use with MILSTAR satellites.

During 1982, the Navy awarded an engineering development contract for MILSTAR EHF ship-borne terminals, the Air Force released a request for proposals for airborne MILSTAR terminals, and the Army continued advanced development of the single-channel-objective tactical terminal (SCOTT) at Lincoln Laboratories.

The joint Defense Advanced Research Projects Agency (DARPA) and Navy Submarine Laser Communications (SLC) Program continued developing technology to communicate from space, using a blue-green laser beam to penetrate clouds and water to submarines at operational depths without compromising their security or limiting their flexibility. Early tactical capabilities are expected from an airborne system for limtied areas. A space-based system would provide global coverage, survivability, and flexibility in both tactical and strategic operations, but presents formidable technical challenges. During fiscal 1982, SLC spacecraft design and laser spaceworthiness engineering were started, to assess the concept and to permit allocation of resources to the laser techniques that promise early operational applications. The first SLC satellite (*SLCSAT 1*) is expected to resolve technical and operational issues and to have a limited operational capability.

Advanced Space Communications Technology

The Advanced Space Communications program develops technology, techniques, and concepts to improve present and future military satellite communications systems. In 1982, testing of the AN/ASC-30 airborne-command-post communications terminal was completed.

NASA and the Air Force continued a cooperative program to develop components for a satellite communications system in the 20-GHz frequency range. The program is developing both solid-state and traveling-wave-tube amplifiers for satellite downlink transmitters.

Navigation and Geodesy

The Navy navigation satellite system, TRANSIT, provides worldwide positional data for strategic ballistic-missile submarines and many other military and commercial users. TRANSIT completed 17 years of operation in 1982.

The Navstar Global Positioning System (GPS) is a space-based radio-positioning, navigation, and time-dissemination system that will improve weapon delivery, worldwide rapid-deployment, and intelligence and reconnaissance capabilities. The operational system will be deployed by late 1988, with 18 satellites providing positioning information accurate to 16 meters, velocity accurate to 0.1 meter per second, and time synchronization to within 0.1 microsecond. GPS is being developed by a joint program office with representatives from the Air Force, Army, Navy, Defense Mapping Agency, Department of Transportation, and nine North Atlantic Treaty Organization (NATO) countries.

In 1982, development of GPS reached significant milestones. Congress approved and the Air Force initiated a multiyear, block-buy procurement of 28 satellites to establish the GPS constellation. Competing contractors Rockwell/Collins and Magnavox—awarded contracts in 1979 to develop a family of GPS user equipment to satisfy the requirements of all participating services and agencies—delivered test models for initial field testing for Army applications following completion of final factory tests in November 1982. Field testing will begin in March 1983. First deliveries of prototype user equipment configured for representative aircraft, ship, and submarine platforms are scheduled for 1983. Testing will continue into 1984.

Testing of engineering models of user equipment continues to confirm the versatility and accuracy of the GPS. Landing and approach tests with a helicopter, emphasizing navigation through the transition to hover, yielded typical accuracies better than 10 meters.

The *Landsat 4* satellite, launched in July 1982, is determining its position in space with the first space-qualified GPS receiver. The receiver provides navigation and timing information for Landsat earth imagery and for mapping. Participating North Atlantic Treaty Organization (NATO) nations conducted numerous demonstrations using GPS, including a flight over the North Pole by a United Kingdom aircraft equipped with a GPS set, aided by an altimeter for navigation through periods of poor satellite visibility.

The Navy began the Geodetic/Geophysical Satellite (*Geosat*) program in 1982. *Geosat*, scheduled for launch in 1984, will provide data to improve accuracy of the marine geoid, completing the data collection begun by NASA's remote-sensing satellite, *Seasat*, during its brief life in 1978. The *Geosat* sensor will duplicate the *Seasat* radar altimeter on a bus module derived from the GEOS Geodetic Satellites. An 18-month mission is planned to provide a homogeneous geoid data base and to detect bathymetric hazards to submerged navigation.

Meteorology and Oceanography

The Defense Meteorological Satellite Program (DMSP) provides high-resolution visible and infrared cloud imagery, atmospheric soundings for moisture content and temperature, and ionospheric monitoring to support DoD strategic and tactical weather requirements. Data are stored on board the satellite for readout to U.S.-based ground stations or are provided in real-time to Air Force, Navy, and Marine Corps mobile readout stations or Navy carrier task forces. The stored data, played back from satellites when over the United States, are processed by the Air Force Global Weather Center or the Navy Fleet Numerical Oceanography center for distribution. The Air Force and Marine Corps have just begun procuring new, deployable, tactical vans that can be transported in C-130 aircraft; the first units have been operationally deployed.

DMSP provides entire earth coverage at least four times daily. The data are merged with Department of Commerce environmental satellite data to provide real-time meteorological support to U.S. military forces around the globe. Tactical aviation forecasts, general weather and severe weather forecasts, and tailored forecasts for specific weapons, sensors, and platforms are routinely available 24 hours each day for all areas.

Seasat demonstrated that data describing the surface of the world's oceans can be collected by satellite. These data can improve the accuracy of the tactical atmospheric and oceanographic information required by the military forces. The Navy, with NASA and National Oceanic and Atmospheric Administration (NOAA) support, is considering the development of a Navy Remote Ocean Sensing System (*N-ROSS*), an oceanographic satellite to provide this information.

Surveillance and Warning

Early-warning satellites provide early-warning data on missiles to the National Command Authorities, the Strategic Air Command, and the North American Air Defense Command.

Space Surveillance Research and Development. Significant progress was made in 1982 in collecting infrared radiation measurements with sensors carried on a high-altitude balloon and a probe rocket. The infrared data on earth backgrounds and rocket exhaust plumes will make a major contribution to developing a missile-warning system that can survive adverse conditions. Advanced technology will also improve timeliness and accuracy of attack assessment.

DARPA continues to support development of advanced surveillance technology for future infrared and radar sensors deployable on surface, airborne, and space-based platforms. That technology, applicable to broad-area surveillance, is complemented by a precision pointing and tracking program called Talon Gold, begun in 1979. DARPA completed the preliminary design of the Talon Gold demonstration experiment critical to proving the feasibility of space laser technology. In 1982, a single contractor was selected for the detailed design, fabrication, and testing.

The Teal Ruby experiment is to demonstrate the infrared-mosaic sensor from space. In 1982, DARPA emphasized development of the infrared-mosaic focal-plane and signal-processing technologies applicable to airborne surveillance as well as space surveillance. Key portions of the program, including infrared-detector arrays and advanced digital-signal processing components, have been successfully demonstrated.

Advanced Microwave Technology. In 1978, DARPA and the Air Force began developing technology for monolithic, microwave-radar-transceiver components to make new, high-density, phased-array antenna systems possible. The technology has been developed in both silicon on sapphire and gallium arsenide, making it possible to perform all of the radar-antenna module's transmit-receive functions on a single chip—potentially reducing weight and cost of phased-array systems by several times that of present systems. Applications and novel concepts for space-based, airborne, and surface radars and communications systems have been identified. Work is continuing on advanced membrane antennas, with an active array-antenna test planned in 1983.

U.S. Naval Space Surveillance System. NAVSPASUR, part of the North American Aerospace Defense Space Detection and Tracking System (SPADATS), detects and tracks satellites and other space objects. The Systems Computational Center in Dahlgren, Virginia, maintains a catalog of space objects. NAVSPASUR continued its planned multiyear modernization during 1982. The modernization will replace much of the original hardware installed in 1961 with digital receiver, transmitter, and data-processing equipment and already is improving system accuracy and sensitivity.

Antisatellite System. The U.S. antisatellite (ASAT) program is being developed in response to Soviet development of operational ASATs. The main U.S. weapon component is a miniature vehicle interceptor that will be air-launched by an F-15 aircraft using a two-stage SRAM-ALTAIR booster combination.

Space Transportation

Expendable Launch Vehicles. During 1982, DoD launched six expendable launch vehicle missions on Titan III and Atlas E vehicles. One of these missions, launching a dual payload, was the first flight of the Titan III(34)D with the inertial upper stage, which was developed to provide an expendable launch vehicle configuration for both prime launch and Space Shuttle backup applications. The program to integrate the inertial upper stage onto the Titan III was begun in June 1977.

Space Shuttle. NASA and DoD are partners in the development and operation of the Space Shuttle. NASA has development and operational responsibilities for the Shuttle vehicle, the East Coast Shuttle launch and landing facilities at Kennedy Space Center, Florida, and Mission Control Center at Johnson Space Center, Texas. The Air Force is developing the inertial upper stage and will develop and operate the West Coast launch and landing facilities at Vandenberg Air Force Base, California, for both defense and civil missions. Vandenberg, needed for polar-orbiting missions, is scheduled to be ready for Shuttle operations in October 1985. The Air Force is also funding modifications of existing NASA facilities and equipment to permit classified operations at Johnson, Kennedy, and Goddard Space Centers and has begun acquisition of the Consolidated Space Operations Center near Peterson AFB, Colorado, to augment the Satellite Control Facility in Sunnyville, California, as well as Shuttle mission control capabilities at JSC.

The Air Force participates in the Shuttle program to ensure effective support of national defense missions. Although NASA has overall responsibility for the Space Transportation System, the Air Force defines DoD's operational and support requirements and assesses the effect of Shuttle design changes on national security missions. It considers unique DoD needs to ensure maximum operational use of the expanded capability offered by the Shuttle. The long-term advantages of the Shuttle to DoD appear to be substantial, particularly for payload retrieval, in-orbit repair, assembly of very large structures in space, and the availability of an orbital test bed—modes of operation unavailable without the Shuttle.

The fourth and final orbital test flight of the Space Shuttle—which landed at Edwards AFB, California, on the Fourth of July, 1982—carried the first DoD experimental payload. DoD's first operational use of the Shuttle is scheduled for a launch from KSC in 1983.

Inertial Upper Stage (IUS). The Air Force is developing the IUS as an expendable upper stage for use with the Space Shuttle, to transfer payloads from the Shuttle's low earth orbit to the mission orbits. The IUS, also used on the Titan III(34)D launch vehicle for certain DoD payloads, is to be used with the Shuttle by both DoD and NASA for large high-altitude payloads. The first, highly successful, launch of IUS was in October 1982 on the Titan deploying a DSCS II and DSCS III payload. Its first launch on the Shuttle is scheduled for early 1983 (the sixth Shuttle flight), when it will carry the first Tracking and Data Relay Satellite into geosynchronous orbit.

NASA/DoD Centaur Upper Stage. Present Space Shuttle upper stages include the commercial PAM-D and PAM-A payload assist modules (also called SSUS-D and SSUS-A, spinning solid upper stages), which can carry 450 and 900 kilograms to geosynchronous orbit, in addition to the Air Force inertial upper stage (2300 kg to geosynchronous orbit). Because these stages provide less than the desired capability for the *Galileo* orbiter-probe mission to Jupiter in 1986, the Congress directed NASA to proceed with development of the Centaur upper stage for planetary exploration missions. The congressional direction, combined with several other new factors, led DoD to enter joint Centaur development with NASA. These factors included:

- The development schedule for one DoD satellite slipped, permitting direct integration with the Centaur stage instead of dual integration with IUS and a new, higher energy upper stage—thus promising lower cost over the long term.
- DoD can now retain the IUS for certain missions, ensuring continuity of launch operations during Centaur development.
- DoD was able to restructure IUS contracts to minimize the cost effects of NASA's use of Centaur instead of IUS for planetary missions.
- DoD worked out a financial arrangement with NASA that limits both the total investment and the effect of Centaur development on the near-term budget.

NASA and the Air Force signed a memorandum of agreement defining the management and financial arrangement for a joint program to develop two Centaur configurations. The Centaur G, six meters long and able to launch 4500 kg from the Shuttle to geosynchronous orbit, will be the program's baseline configuration for common use by NASA and the DoD; a stretched Centaur G will provide increased performance for the *Galileo* mission to Jupiter.

Space Vehicle Subsystem R&D. The Air Force continued development of advanced spacecraft subsystems for space navigation and guidance and continued planning space technology. The space sextant, test-flown during 1982, demonstrated that it could survive the launch environment and could precisely measure angles between stars while in orbit. Combinations of such included angle measurements and angular measurements between stars and the earth or the moon's limb permit the sextant to navigate autonomously and to determine precise attitude for its host spacecraft. Development of the Military Space Systems Technology Model (MSSTM) continued, for advanced technology planning. MSSTM provides Air Force planners a broad overview of potential military space missions and defines technology development needed for the projected capability.

The Air Force Space Test Program's Spacecraft Charging at High Altitude (SCATHA) experiment, which was launched into geosynchronous orbit in 1979, continues to provide extensive data on electrical charging. In 1982, the Air Force, NASA, and others were using the data to develop new design requirements that will minimize the effects of charging and discharging on spacecraft systems.

The Space Test Program provided launch, integration, and coordination support for four Navy space experiments during 1982. Two experiments were sponsored by the Office of Naval Research. One is measuring heavy ions to provide data for analysis of electronic-equipment shielding requirements. The other is measuring electron precipitation from high-powered, very-low-frequency (VLF) transmissions.

Aeronautical Activities

Fixed-Wing Programs

Bomber Development. All four major associate contractors (Rockwell, Boeing, GE, and AIL division of Eaton) received full-scale development contracts for the B-1B multirole bomber early in 1982, and 24 percent of the total program is committed under firm-fixed-price contracts. Final engineering reviews for the associate contractors were completed in April, the Strategic Air Command's system operational concept document was published in September, and the test and evaluation master plan was to be submitted to the Office of the Secretary of Defense in January 1983. Key milestones include rollout of the first production B-1B in October 1984, first B-1B flight in March 1985, initial operational capability in September 1986, and full operationial capability in June 1988. The plan is to acquire 100 B-1Bs for an estimated $20.5 billion (in constant 1981 dollars).

B-1A number 4 participated in the 1982 international air show at Farnborough, England. After its return and exhibition at Andrews and Offutt Air Force Bases, work began to modify the aircraft to receive the newly developed offensive and defensive systems. Starting in July 1984, it will be the test bed for the heavyweight buildup (to increase the maximum gross weight at takeoff from 179 000 kg to 216 000 kg), offensive and defensive avionics integration testing, evaluation of the performance of the terrain-following and terrain-avoidance system, and testing B-1B performance and operational flying qualities in adverse weather conditions.

The time-phased, combined B-1B and advanced technology bomber (ATB) program permits orderly development with early attention to risk reduction. Progress on technology in support of the ATB is promising, but the major advances required indicate that concentrating solely on an accelerated ATB program would entail high risk. The combined program will provide transition to a mixed force of penetrating bombers and cruise missiles to deter an enemy through the 1990s and into the next century.

F-14 Alternate Fighter Engine. Grumman Aerospace Company and Navy pilots flew 44 flights in an F-14B aircraft with two General Electric F101 engines from 14 July 1981 through 26 March 1982. Pilots explored virtually every corner of the flight envelope and moved throttles without restriction. Although the aircraft was not sufficiently instrumented to develop quantitative performance data, the program demonstrated inlet compatibility, reliable engine operation, and performance increases. In spite of aggressive throttle movements, there were no inlet distortion stalls, no stagnations, only five stalls in the entire program (all of which were self-clearing), a 98-percent afterburner lighting rate, and no need for throttle restrictions—a limiting factor for present F-14 flight profiles.

F/A-18. The F/A-18 Hornet naval strike fighter—a twin-engine, midwing, multimission tactical aircraft—will replace the F-4 fighter and A-7 light attack aircraft. The program stresses the use of proved technology and places the highest priority on reliability, maintainability, survivability, and operational versatility. Full-scale development was essentially completed during 1982. The operational evaluation was completed in October, and the first fleet unit, a Marine fighter attack squadron of F-4s modernized to F/A-18s, was completed during the latter half of the year. Additional Navy and Marine squadrons will be upgraded to Hornets at the rate of eight per year.

Advanced Tactical Fighter (ATF). The Air Force began to define requirements, focus technology, and develop concepts for an advanced tactical fighter for the 1990s. Mission analyses have indicated the need for an ATF that will survive and be more effective against a rapidly growing threat (in both quantity and quality). The Air Force has been working with industry to identify a range of concepts and the supporting technology that must be developed. The ATF will take advantage of a broad spectrum of advanced technology, including short takeoff and landing to reduce runway dependence and increase deployment flexibility, greater aircraft agility to increase survivability and engagement options, greater speed and altitude to improve survivability and to deny potential enemy sanctuaries, techniques to decrease probability of detection, increased range and payload capabilities to increase both deployment and employment choices, better vehicle and weapon integration to minimize the penalty paid to deliver munitions to the desired target, and improved system reliability to reduce support cost and increase effective force availability.

C-5A Wing Modification. The purpose of the wing-modification program is to allow the C-5A aircraft to attain full mission capability and to reach its design goal of 30 000 hours of service life. The program began in December 1975. Air Force Systems Command has program management responsibility (PMR) for research, development, test, and evaluation (phase I and II), scheduled for completion in October 1983. Air Force Logistics Command is responsible for production (phase III and IV), scheduled for completion in July 1987.

The fatigue test article X-991 successfully reached 90 000 cyclic test hours (CTH), the equivalent of three lifetimes of design use, in April 1982. Fatigue article testing terminated at 105 000 CTH in November. At 85 000 CTH, the severity of the test loads was increased to represent a wartime contingency. The first 60 000 CTH validated the fatigue life of the wing, and the follow-on 45 000 CTH tested crack propagation. The testing validated the crack-growth analysis and characteristics of the modified wing structure, to provide data for a structural monitoring program for the C-5A fleet. Further tests will assess the residual strength of the wing after severe structural damage (such as that from engine blowup or war damage). All testing will be concluded in early 1983 and the final report submitted in late 1983. In November 1982, the San Antonio Air Logistics Center contracted for procurement of 18 sets of wing mod kits and for installation of kits on 16 aircraft, making a cumulative total of 52 kits and 22 installations on contract.

C-17. The Air Force awarded a contract to McDonnell Douglas Corporation to begin low-level development of the C-17 transport aircraft. Initial investigations are aimed at advancements that would be useful in any follow-on cargo-aircraft development. These technology areas, which were identified by NASA, are (1) externally blown flap systems on swept, supercritical wings; (2) directed thrust reversers that reverse the entire engine flow, both fan and hot core; (3) aircrew work load for three-man crew operations and a two-pilot cockpit configuration for tactical airlift missions. This low-level effort will lay the groundwork for a program leading to a follow-on airlifter in the early 1990s.

Next-Generation Trainer. Fairchild and Garrett Corporations won full-scale development contracts for the air vehicle and engine for the next-generation trainer (T-46A), and development is progressing. The T-46A will replace the T-37 primary trainer in Air Force undergraduate pilot training, correcting inefficiencies and performance deficiencies of the T-37 while alleviating a T-37 fleet insufficiency projected for 1987. The initial operational capability will be in 1987, and a total purchase of 650 aircraft is planned through 1992.

VTXTS. Because of high operating and support costs, as well as pending obsolescence of present Navy jet-flight-training aircraft, the Navy has begun a program to replace them. VTXTS is to integrate aircraft, simulators, training management systems, and academics into a cost-effective system to provide qualified jet pilots. After parallel industry studies and proposals for pre-full-scale development, a prime contractor team was selected in 1982.

Remotely Piloted Vehicles (RPV). The Army's remotely piloted vehicle will perform target-acquistion, designation, aerial-reconnaissance, and artillery-adjustment missions. A small unmanned air vehicle, including its mission payload, is controlled from a ground station, and video imagery and target-location information are returned via a jam-resistant data link. Full-scale engineering development of the RPV continued from 1 October 1981 to 30 September 1982, with the first flight in July 1982. Four 1982 flights demonstrated telemetry of video imagery to the ground control station and computer-controlled launch, recovery, and navigation. The cost-plus-incentive-fee contract awarded Lockheed Missiles and Space Company in 1979 calls for 22 air vehicles, 18 mission payload subsystems, 4 ground control stations, 3 launchers, and 3 recovery subsystems.

Cruise Missile Programs

Air-Launched Cruise Missile (ALCM). The ALCM, a key element in the bomber leg of the U.S. Triad of land, air, and sea forces, provides the U.S. bomber force greater weapon accuracy, flexible routing and targeting, reduced exposure to enemy defenses, and saturation of defenses. Initially, B-52G aircraft will carry 12 ALCMs loaded on two external pylons, while retaining the internal capability to carry short-range attack missiles and gravity weapons through fiscal 1986.

Beginning in fiscal 1986, ALCMs will be loaded externally on B-52H aircraft. Future plans include internal loading for a total load of 20 missiles each. The B-1B and the advanced technology bomber will also be able to carry cruise missiles.

At the end of 1982, the ALCM program was concurrently in full production and follow-on operational test and evaluation, with 1145 ALCMs under contract. The 20-flight test program begun in 1980 was completed in September 1982. The initial operational capability of an entire B-52G squadron, with each aircraft equipped with 12 external ALCMs, was achieved in December.

Sea-Launched Cruise Missile (SLCM). SLCMs are key weapons in the Navy's tactical and strategic inventory. The Harpoon weapon system, operational with the U.S. Navy, extends the range for antiship attack capabilty of submarines, surface ships, and aircraft. During 1982, the Harpoon system was installed on additional U.S. Navy ships and submarines.

The Tomahawk SLCM weapon system, completing development in 1982, provides both land-attack and antiship cruise missiles sized to fit torpedo tubes and can be launched from submarine, surface, air, and land launch platforms. The Tomahawk antiship missile (TASM) will be able to deliver a conventional warhead against heavily defended surface combatants at extended ranges. The Tomahawk land-attack missile (TLAM) will carry either a conventional or nuclear warhead and provide Navy operating forces a distributed strike capability with survivability. During 1982, developmental testing was conducted for both the TASM and TLAM at the Pacific Missile Test Center, Point Mugu, California.

Ground-Launched Cruise Missile (GLCM). The long-range Air Force GLCM, a key element of the NATO theater nuclear-force modernization program, is designed to survive an enemy first strike. Its development should enhance deterrence and help compensate for any enemy numerical superiority in conventional and theater nuclear forces.

The system incorporates the Tomahawk cruise missile with ground-launch equipment consisting of a transporter-erector-launcher and a launch control center. Each launcher, containing four missiles, is mounted on a semitrailer with electronic and power-production equipment. The control center, also on a semitrailer, houses the launch crew and equipment for communications, missile status monitoring, and missile launch.

The system is now undergoing development and initial operational testing. All seven launches through 1982 were successful except for two missile-related problems. Three more flights are planned in early 1983. Initial deployment is scheduled to begin in the United Kingdom in December 1983, followed by deployments in Italy. The full deployment plan, for 464 missiles based in five European countries, is to be completed in 1988.

Helicopter Programs

UH-60A Black Hawk. The Black Hawk utility helicopter provides the Army cargo and troop-carrying support necessary to sustain ground forces in warfare. Sikorsky and General Electric were awarded successive production contracts from fiscal 1976 through fiscal 1981, for 337 aircraft and engines. In fiscal 1982, Sikorsky received a multiyear contract for 1982–1984, for 294 aircraft, to total 631 Black Hawks under contract. The Army had accepted 318 by 15 September 1982.

The Black Hawk is in service in high-priority Army Forces Command units, and deliveries have begun to units in Europe. Korea will begin receiving aircraft in October 1983, and follow-on deliveries will continue to continental U.S. units. The UH-60A will substantially improve operational capability to carry a combat-equipped squad of 11 men, or comparable cargo, in all weather, day or night, in all operational environments including the Middle East. It is meeting all user requirements.

SH-60B Sea Hawk. A Navy-developed derivative of the Black Hawk, the Sea Hawk is the airborne part of the LAMPS MK III sea-air antisubmarine warfare system. The aircraft and engine have been modified to endure the more severe environmental conditions met in operating helicopters from small ships (DD-963 class destroyers and FFG-7s). Full production of the SH-60B began in 1982. The Navy is considering a derivative of the SH-60B to replace the aging fleet of SH-3s to give the carrier battle group inner-zone protection against submarines. This helicopter will be designated the SH-60F.

HH-60D Night Hawk. A program to develop and field a new helicopter for USAF combat rescue and special operations forces began in 1982. The aircraft, designated the HH-60D Night Hawk, will be a derivative of the Army UH-60A Black Hawk and Navy's SH-60B Sea Hawk and will be capable of long-range, unescorted flight at night and in adverse weather conditions. Sikorsky Aircraft is under contract for the air vehicle and necessary modifications, while a separate contract has been awarded to develop and integrate the avionics subsystem. Production is scheduled to begin 1985, with initial operational capability in 1987. Delivery of 243 aircraft is planned from 1987 to 1993. The HH-60D will use the same GE-401 (T-700-derivative) engine as the Navy's Sea Hawk.

CH-47 Modernization. The CH-47 modernization program will provide the Army a medium-lift helicopter beyond the year 2000. Engineering development, begun in June 1976, has produced three prototype CH-47D models incorporating modernized rotor, drive, hydraulic, electrical, advanced-flight-control, cargo-handling, and auxiliary power unit systems. Integration of these changes is designed to improve operational characteristics and produce one standard CH-47 configuration, to facilitate logistical support and maintenance. The first production contract for nine helicopters was signed in late 1980. By the end of 1982, the three CH-47D prototypes had flow more than 2200 test hours, with the high-time aircraft surpassing the 1300-hour mark through extended reliability, availability, and maintainability (RAM) testing and desert operations. The fiscal 1982 contract, awarded in December 1981, will modernize 19 aircraft. The approved program will modernize the entire fleet of 436 CH-47A, B, and C helicopters to the CH-47D configuration. Deliveries of the first production aircraft were to begin in February 1983. The first Army Aviation unit fully equipped with 24 CH-47D helicopters is to be operational in early 1984.

Cobra/TOW. Modification of existing AH-1G helicopters and purchase of new production aircraft continued. Deliveries of the first AH-1S model Cobra—equipped with the tube-launched, optically tracked, wire-guided (TOW) missile—began in June 1975. Since that time the Cobra/TOW has been upgraded three times, leading to the present fully modernized AH-1S. Key improvements include addition of survivability equipment, 20 mm gun, computerized fire control, laser range finder, rocket-management system, and upgraded engine and drive-train components.

On completion of the program in early fiscal 1985, the inventory will consist of about 500 fully modernized AH-1S models and 488 older models. The Army is evaluating a program to upgrade the older aircraft and include a forward-looking infrared (FLIR) sight system for day and night fighting capability in reduced visibility environments.

C/MH-53. The Navy is converting CH-53E aircraft to the MH-53E configuration for airborne mine countermeasures (AMCM). The conversion will provide the tow-tension, endurance, and lift capacity required to employ the necessary equipment. During 1982, the Navy awarded a development contract for the conversion, also beginning prototype design, fabrication, and engineering analysis of a longer-life tail-rotor system and night vision system.

AH-64 Apache Advanced Attack Helicopter. The Apache completed an extensive developmental flight-test program of more than 4000 hours. Production began in 1982 with a first-year purchase of 11 aircraft of a planned 515. At the end of the year, all production activities were on or ahead of schedule, and construction of the final assembly facility at Mesa, Arizona, was well ahead of schedule. The first production Apache was scheduled for delivery to the Army in February 1984, with the laser-equipped Hellfire antitank missile and sights that permit day, night, and adverse weather operations.

Synthetic Flight Training. The Army continued research, development, and acquisition of flight simulators. In August 1982, the Army awarded American Airlines a contract for the final portion of the rotor systems integration simulator (RSIS), a highly versatile, high-fidelity, rotor-wing simulator that will be a key element in future aircraft selection, in improving existing rotor-wing aircraft, and in formulating computer software for training simulators.

In July 1982, the Army let a contract for development of the prototype simulator for the AH-64 Apache helicopter. The AH-64 combat-mission simulator is designed to provide training in normal operating procedures, emergency procedures, target designation and acquisition, and weapon delivery. Its pilot and copilot-gunner stations will train pilots from aircraft transition to full combat capability. The device will be ready for pilot training by June 1985.

The Army's CH-47C-model simulator program was proceeding on schedule at the end of the year. The first three production models were in use. In 1983 the Army will exercise a contract option for two CH-47D simulators and for converting the fielded C-model simulators to D configuration. Conversion, to begin in 1984 and be completed in 1985, is to provide pilot training as CH-47 modernization progresses.

The first production AH-1S-model Cobra simulator is scheduled for fielding in late 1983. The Army plans eight production models, two for the Army National Guard. The simulator consists of two cockpits, replicas of the AH-1S pilot and copilot-gunner stations, with an instrument station aft of each. This simulator permits pilot and gunner training separately and as a team and includes a visual system that provides day and night scenes, as well as weapon effects.

V/STOL Program

AV-8B. More than 500 hours of flight tests of four full-scale development AV-8B aircraft completed Navy technical evaluations I and II and the first stages of Navy operational test and evaluation. An improved, vectored-thrust, vertical or short takeoff and landing (V/STOL) aircraft for the Marine Corps, the AV-8B is based on the AV-8A aircraft and the Pegasus I engine. The AV-8B will double the range and payload performance of the AV-8A model and will be more reliable and easier to maintain.

Joint Services Vertical Lift Development (JVX)

In December 1981, the Army was designated the executive service to develop a common DoD vertical takeoff and landing (VTOL) vehicle. A joint technology assessment, completed in the spring of 1982, reviewed JVX concepts that would take advantage of emerging advanced VTOL technology and meet mission requirements of all services. JVX will provide a multimission capability using a common airframe and possibly a common engine. Each service will use its own mission equipment. The Marine Corps defined an assault lift vehicle as part of the triservice program. The Navy will use it for combat search and rescue, the Air Force for special operations and search and rescue, and the Army in a special electronic-mission role. The services expected to issue a request for proposals in fiscal 1983. The Marine Corps will achieve the initial operational capability in late 1991, with aircraft for other services expected by 1993. The lead service responsibility was transferred from the Army to the Navy in December 1982.

Aeronautical Research and Development

Forward-Swept Wing. A joint DARPA-USAF-NASA program will demonstrate the feasibility and practical application of a forward-swept wing and related flight-control technology in an experimental flight-test aircraft, the X-29. Grumman Aerospace Corporation is assembling the aircraft for a first flight in early 1984. By using advanced composite materials and aeroelastic tailoring, the nonmetallic wings can be made up to 30 percent lighter than metal wings of the same strength. Other advanced technologies in the X-29 design include digital fly-by-wire flight control, a variable-incidence close-coupled canard, discrete-trailing-edge variable-wing camber, and highly relaxed (negative), static longitudinal stability. In addition to decreased aircraft size and weight, the forward-swept-wing technology offers reduced transonic drag, improved low-speed flying qualities, and greater maneuverability at transonic and supersonic speeds.

Advanced Fighter Technology Integration (AFTI). The Air Force AFTI program began flight-testing a modified F-16 in July 1982. The test aircraft integrates a triple-redundant, digital-flight-control system with vertical canard control surfaces to achieve independent six-degree-of-freedom control, thus improving agility and flexibility. Investigation of the new flight control features and handling qualities will continue through mid-1983. During the second phase of the program, the advanced system will be integrated with a fire control system to achieve highly accurate maneuvering-attack capability.

Aeronautical Technology Research. The Army pursues exploratory development and scientific knowledge in aeronautical technology to increase operational effectiveness of helicopters, reduce life-cycle costs, improve availability, reduce vulnerability, and improve flight simulation and analysis of helicopter system integration. Disciplines include aerodynamics, structures, propulsion, reliability and maintainability, safety and survivability, aircraft subsystems, mission support, flight simulation, and man-machine integration.

Tests of the no-tail rotor (NOTAR) demonstration aircraft, which uses a circulation-control tail boom and jet thruster for antitorque and directional control, showed adequate performance and reduced noise signature. A study of devices to improve helicopter autorotative capabilities to increase flight safety was completed. Three concepts for curved fuselage frames made from composite materials were developed and tested. Testing of a scale model of an aeroelastically conformable rotor showed that tailoring of blade stiffness and aerodynamic parameters can reduce loads and improve performance.

Cost-effective techniques for fabricating cooled radial turbines were defined and validated. A feasibility study of adaptive fuel-control concepts that permit electronic fuel controls to change characteristics while in operation was completed with encouraging results. New inspection and repair techniques for helicopter wiring damaged in battle permit rapid fault isolation and repair. Flight test for the oil-debris discrimination and filtration system completed 75 000 hours, leading to a recommendation to extend the oil-change interval on all UH/AH-1 helicopters to 1000 hours, for an estimated yearly saving of $3 300 000. Chemical-infiltration and air-leak tests on an AH-1S helicopter assessed the sealing in the cockpit area required for overpressure, to preclude contamination by chemical agents. User evaluation of the internal cargo-handling system on the CH-47 was successfully completed. Preliminary design methodology for a wide variety of VTOL concepts was updated, extended, and applied to evalution of candidate designs for the JVX.

Advanced Digital-Optical Control System (ADOCS). The ADOCS program seeks to develop an advanced flight-control system to increase battlefield effectiveness of Army helicopters while reducing their cost and weight.

Redundant digital-optical hardware will be developed to protect against lightning, electromagnetic pulse, and nuclear radiation. Optics, immune to electrical interferences, will provide protection even with composite structures that offer no inherent electrical shielding. Studies have shown that digital flight control improves helicopter handling. significantly improving mission effectiveness.

The ADOCS program is developing and flight-testing a digital control system that is as electrically passive as possible. A computer, or microprocessor complex, generates actuator control signals in response to commands from the pilot, aircraft-state data from onboard sensors, and system feedback from electrically passive, optical transducers. All essential control-system data are communicated digitally over optical fibers, with redundancy as necessary for reliability and survivability. Two control-media-mechanization contracts were completed in fiscal 1981. Optical servovalve contracts and linear, rotary, differential-pressure-transducer contracts were essentially complete at the end of 1982. An advanced rotor-actuation concept was selected for analysis. The advanced-cockpit-controls and automatic-flight-control system, with the balance of its phase II simulation to be completed in January 1983, is providing preliminary design information on control laws, controller configurations, and display formats for the flight demonstrator program.

Boeing Vertol, awarded a contract to design, fabricate, and flight-test a redundant digital-optical flight control system in a UH-60-A helicopter, completed its preliminary design in October 1982. After detailed design, the first flight is planned for November 1984. Contract completion is expected in fiscal 1986.

Air Mobility Research. The Army conducts basic research in the aerodynamics of rotor systems and rotary-wing and V/STOL aircraft; in advanced propulsion systems; and toward developing materials, structures, and aviation electronics for future aircraft. Particularly noteworthy accomplishments in 1982 were in aeromechanics, propulsion, and structures. A three-dimension, transonic, inviscid, aerodynamics code that predicts the flow field and pressure distribution in the region of a rotor-blade tip in hovering flight was developed and applied. This code, and its extension to forward flight, is fundamental to accurate prediction of rotor noise, rotor design loads, and performance.

Significant advances were demonstrated in the use of optical (laser-light-source) interferometry. This new, non-intrusive, measurement technique provides an excellent tool for validating the newly developed transonic code and for developing new wake-geometry codes.

Tests of a model helicopter rotor in two advanced anechoic wind tunnels, in France and the Netherlands, were completed in cooperative research with France and Germany. The tests provided an extensive data base for understanding rotor noise-generation. The data have already shown that these results are scalable so that small-scale wind-tunnel models can be used to study full-scale acoustic phenomena. A felt-ceramic combuster-liner material appears to offer great advantages for future gas-turbine-engine combusters requiring extremely low coolant flows. A simple test was developed that measures the interlaminar fracture toughness of multilayered, fibrous, composite materials. NASA is using this test to screen toughened resin-graphite composites for primary structural components. Its application to helicopter structures is straightforward and may be used to evaluate new, low-cost composite materials.

Advanced Composite Airframe Program (ACAP). ACAP seeks to demonstrate the use of advanced composite materials and structural design concepts in helicopter airframes to reduce weight by 22 percent and cost by 17 percent, provide tolerance to 12.7 mm and 23 mm high-explosive incendiary weapons, reduce radar cross-section, improve crashworthiness and laser burn-through resistance, reduce maintenance, and lengthen life. The program seeks to establish industry and Army confidence in composites for primary and secondary airframe structures for operational helicopters. Resulting technology will also be applicable to all future aircraft.

Bell Helicopter Textron is using dynamic and operational components from its model 222 commercial helicopter for the demonstration, while Sikorsky Aircraft is using dynamic and operational components from its S-76. They completed detailed design and analysis of the airframe structure and landing gear for both configurations in 1982 and tested coupon and cross-section specimens of representative materials and joint designs. One-fifth-scale wind-tunnel models of airframe configurations verified drag predictions and static stability characteristics. Critical design reviews of airframe and landing gear design, analysis, and supporting test data were completed. The final phase of the program, begun in late 1982, includes airframe fabrication, full-scale structural test, flight vehicle assembly, and ground and flight tests. Tests will include static and dynamic testing, crash testing, and ballistic testing. First flight of the ACAP aircraft is scheduled for late 1984, with the entire program scheduled for completion in 1985.

Avionics. Two contracts were awarded in 1982 for the nap-of-the earth (NOE) communications program. Both contracts (for improved FM and HF-single side band) are proceeding well, with first article tests scheduled for late 1983. Plans are to initiate Army participation in the microwave landing system (MLS) program by installing MLS at the training fields at Fort Rucker and Troy, Alabama. R&D for the full joint tactical MLS has been curtailed. Ways to strengthen available small MLS equipment for mobile configuration are being studied as a possible means of meeting the Army's requirements. "Digitizing" the UH-60 helicopter designated as the system test bed for avionics research (STAR) made progress. Plans are to have a fully integrated digital cockpit by the end of 1983 for flight demonstrations. The program is to provide lighter weight, lower cost aircraft electronics that are more likely to survive in combat.

Joint-Technology Demonstrator Engine. A Navy-Air Force program is substantiating performance, structural integrity, and reliability of advanced gas-generator and low-pressure-spool components in integrated engine tests. Three demonstrator engines demonstrated satisfactory performance, starting characteristics, reduced specific-fuel consumption and broad-area variable-geometry characteristics.

Multiapplication Core Engine. A Navy-Air Force program for designing and fabricating early prototype versions of the next generation of large, high-thrust, tactical-aircraft engines is directed to increase reliability and durability significantly and reduce life-cycle costs. Initial concept definition studies on 16 different systems in 30 configurations have been completed as the basis for a joint Navy-Air Force long-range propulsion plan. Design was begun for joint core-engine concept validation.

Hypersonic Missile Propulsion. NASA is participating in a Navy assessment of advanced propulsion possibilities for hypersonic cruise missiles. NASA's Langley Research Center has developed an air-breathing-propulsion concept that has potential for a variety of naval and other military missions requiring hypersonic missile speeds over long ranges.

Lightweight Hydraulic System. The increasing hydraulic-power requirements in complex aircraft such as the F-14, the reduced space in aircraft such as the F/A-18, and the desire for minimum weight in V/STOL aircraft such as the AV-8B have added impetus to reduce subsystem weight in future aircraft. The Naval Air Development Center has investigated the potential of a lightweight hydraulic system, culminating in a laboratory system simulating an actual aircraft installation. The lightweight system operates at a pressure of 540 atmospheres (8000 pounds per square inch) rather than the present 200 (3000 psi). Early investigation established the desired pressure level after exploring a range up to 1360 atmospheres (20 000 psi), determined that damage system characteristics were no more severe for 540 than for 200 atmospheres, and evaluated the effects on actuator, pump, and related subsystems. Design analysis, using test results, indicates that the total hydraulic system weight of a typical carrier-based tactical aircraft can be reduced by 30 percent and the volume 40 percent.

XV-15 Tilt-Rotor Research Aircraft. The tilt-rotor research aircraft program continued in 1982 with a military demonstration tour of the East Coast by the XV-15 aircraft, including flight demonstrations at several military installations. The aircraft then was prepared for participation in the special electronic-mission aircraft (SEMA) exercises. SEMA instrumentation, radar warning receivers, and chaff dispensers were installed and checked out, and phase I SEMA survivability tests indicated that the tilt-rotor should be a viable SEMA aircraft. Subsequently, the aircraft was flown on a highly instrumented range from China Lake Naval Weapons Center, California, for radar cross-section measurements. Data were taken at various pylon angles and at various aspects to the radar systems. In addition to baseline measurements, a series of measurements were made of chaff fired from the aircraft.

During July and August 1982, shipboard tests of the XV-15 were performed as part of a joint NASA-Army-Navy-contractor operation. Following extensive land-based flight tests simulating ship takeoffs and landings, the Navy-contractor pilot team conducted flight operations for several days from the U.S.S. *Tripoli* (LPH-10) off San Diego, California. All flight-test objectives were realized, and the tilt-rotor was assessed as adaptable to sea-based operations. Both STOL and VTOL operations generally confirmed performance predictions. Hover off the deck at near wheel height met no problems. Takeoffs and landings from various deck spots pinpointed no problem areas. The results of these trials will be of direct use in the present early stages of the JVX program.

V/STOL Aircraft Technology. In a joint program, the Navy, NASA, and Grumman Aerospace Company conducted a series of tunnel and V/STOL stand tests to establish the technical characteristics of a turbofan-powered, subsonic, V/STOL-aircraft concept. Tests of a large-scale model at NASA's Ames Research Center investigated vertical, transition, and forward flight. Results confirmed that the design's flight characteristics would be essentially as predicted from small-scale preliminary models and analysis.

Space and Aeronautics Support

Satellite Control Facility (SCF)

The Air Force SCF controls satellites for DoD from the Satellite Test Center (STC) at Sunnyvale, California, through a worldwide network of seven tracking stations. During 1982, SCF supported 15 launches (1 dual) including 7 DoD and 5 NASA orbital missions and 3 ballistic flight tests. From its tracking station in the Indian Ocean, SCF provided critical orbital coverage for Space Shuttle orbital flight tests. It made 80 600 station contacts providing 94 900 hours of orbital support for satellite programs. The data systems modernization project, a major development program to upgrade the data-processing capability of SCF, is scheduled to provide an operational system in early

1985. The new system will centralize data processing at STC, reducing operating costs at the remote-tracking sites and increasing network capacity. Using the new DoD standard software language, Ada, as a design language, the system has completed critical design review, and coding is progressing on schedule.

Consolidated Space Operations Center (CSOC)

The CSOC integration contract was awarded in 1982, and construction of the facility is scheduled to begin in the summer of 1983 in the Colorado Springs area. CSOC will provide secure management and control for military space operations on the Shuttle. By complementing both DoD's Satellite Test Center and NASA's mission control complex at Johnson Space Center in Texas, CSOC will remove the single-point-of-control aspect for DoD space operations. First satellite control operations are scheduled to begin in 1986.

Eastern Space and Missile Center (ESMC)

ESMC, at Patrick AFB in Florida, provides launch and data-acquisition support for a wide variety of low-inclination-orbit DoD, NASA, and NASA-sponsored space programs and ballistic missile operations. During 1982, ESMC supported 21 major space test operations, including the first operational Space Transportation System mission in November.

Western Space and Missile Center (WSMC)

WSMC, at Vandenberg AFB in California, provides launch and data-acquisition support for DoD and NASA space programs requiring polar orbit and for USAF aeronautical programs. WSMC supported 13 major space test operations during 1982. Aeronautical testing includes that for cruise missile programs. Construction at the western launch site for the Space Transportation System continued at a high level, and preparations continue for beginning MX testing in March 1983.

White Sands Missile Range (WSMR)

WSMR, in White Sands, New Mexico, continued to support DoD and NASA aeronautics and space programs, including NASA's Space Shuttle, upper atmospheric sounding using rockets and balloons, and astronomical test programs. Space Shuttle activities at WSMR include qualification tests on the orbital maneuvering system and on forward and aft reaction control systems, evaluation of Shuttle spacecraft materials, training of astronauts to land the Shuttle, preparation of a satellite system to track and relay Shuttle data back to the earth, and Shuttle flight and landing support. Past efforts include construction of a second landing strip, construction of facilities for post-landing deservicing, preparation for ferrying, preparation of a public affairs plan to handle the multitude of visitors to White Sands during and after landings, provision of overall security support, and conduct of astronaut recovery exercises. White Sands continues preparations for Shuttle landings—training chase aircraft pilots for rendezvous, testing tracking acquisition, testing data transmission, and operating other support systems.

Pacific Missile Test Center (PMTC)

PMTC, at Point Mugu, California, provided back-up support for all Space Shuttle missions, out of its overall capacity to support ballistic missile and aeronautical testing. PMTC's primary emphasis in 1982 was test support for cruise missile programs. Other major testing included the Phoenix AIM-54C, advanced medium-range air-to-air missile (AMRAAM), and AIM-7M missile. Preparations continued for launch and range support for launch certification of the Trident submarine missile.

Naval Astronautics Group (NAG)

NAG is the operational activity responsible for operating the TRANSIT navigation satellite system. Headquartered at Point Mugu, California, NAG provides satellite control, timing, and user services through satellite support stations around the globe for TRANSIT operations.

Arnold Engineering Development Center (AEDC)

AEDC, in Tullahoma, Tennessee, participates in the timely development and continued operational effectiveness of advanced-technology aerospace systems by conducting tests, engineering analyses, and technical evaluations. As a national facility with a broad range of governmental and commercial users, AEDC over the past year supported such projects as the MX missile, Space Shuttle, B-1B and F-16 aircraft, F-100 engine, next-generation trainer, and advanced medium-range air-to-air missile. AEDC operates and maintains some 25 aerospace ground-test facilities, which provide aerodynamic, propulsion, and spaceflight environmental simulations.

Air Force Flight Test Center (AFFTC)

AFFTC, at Edwards AFB in California, conducts development tests and evaluation of manned and unmanned aircraft systems and aerospace research vehicles. Tests range from engineering simulations before flight through flight tests of fully integrated weapon systems. The large air space, dry lake beds, isolation, and highly instrumented ranges provide unique support for a wide variety of users, including NASA's Dryden Flight Research Facility, the Army's Aviation Engineering Flight Activity, and the Air

Force Rocket Propulsion Laboratory. During 1982, the center supported major space, tactical, and strategic systems including the Space Shuttle, F-15, F-16, A-10, F-5, B-52, KC-135, and air-launched cruise missile.

4950th Test Wing

The 4950th Test Wing, an Air Force Systems Command unit based at Wright-Patterson AFB, Ohio, flight-tests military systems, subsystems, and components. It also operates and maintains test and test-support aircraft and ancillary equipment. One of the primary support aircraft is the advanced range-instrumentation aircraft (ARIA), which serves key telemetry, data-processing, and command-and-control functions during both aeronautical test flights and space missions. Conversion from the C-135 to C-18 (used B-707) aircraft and updating of data-acquisition equipment are under way to improve ARIA capabilities.

Cooperation with NASA

Aeronautics and Astronautics Coordinating Board

The Aeronautics and Astronautics Coordinating Board (AACB), cochaired by the under secretary of defense for research and engineering and the NASA deputy administrator, is the major forum for review of policy and program issues of mutual DoD and NASA interest. Its active panels complement the interagency coordination process. During 1982 the AACB met twice (the 87th and 88th meetings), focusing on subjects related to the Space Transportation System. The board resolved to dedicate a meeting early in 1983 to aeronautics.

Cooperative Programs

The Department of Defense—through the Army, Navy, Air Force, and Defense Advanced Research Projects Agency—continues to pursue with NASA research and development programs in space and aeronautics technology. NASA and the Air Force continued a cooperative program to develop components for a satellite communications system in the 20-GHz frequency range. The Navy, with NASA and NOAA support, is considering development of a Navy Remote Ocean Sensing System (*N-ROSS*), an oceanographic satellite to provide tactical information to operating forces.

Cooperation continues in acquiring a fully operational Space Transportation System, including the Space Shuttle, inertial and Centaur upper stages, launch and landing facilities at Kennedy Space Center and Vandenberg Air Force Base, and mission control elements at Johnson Space Center, Goddard Space Flight Center, and the Consolidated Space Operations Center.

DoD and NASA also continue to support each other in expendable launch vehicle operations and spaceflight opportunities for technology development experiments. They are assessing requirements for a prospective Space Station.

Cooperative aeronautical activities include wind-tunnel and flight-test support for aircraft technology development programs: forward-swept wing, advanced fighter technology integration, hypersonic missile propulsion, XV-15 tilt-rotor research aircraft, and V/STOL aircraft technology. Cooperative programs are discussed more fully within the preceding text under the appropriate titles.

Department of Commerce

The National Oceanic and Atmospheric Administration (NOAA), the National Bureau of Standards (NBS), and the National Telecommunications and Information Administration (NTIA) are the Department of Commerce agencies that took part in the nation's aeronautics and space program during 1982.

The NOAA mission is to ensure the safety of the general public and improve the quality of life through better understanding of the earth's environment and more efficient use of its resources. This mission is accomplished by the operation, management, and improvement of the nation's civil, operational environmental satellite systems. Satellite data are used to assess the impact of natural factors and human activities on global food and fuel supplies and on environmental quality. The data also are used to observe and forecast weather conditions, issue warnings of severe weather, and assist community-preparedness programs for weather-related disasters; to prepare charts and coastal maps and for geodetic research; to improve assessment and conservation of marine life; to meet the needs of public and private users including scientists; and for research to improve the nation's environmental service.

The NBS mission is to maintain and develop the national standards of measurement and provide government, industry, and academia the measurement services and fundamental physical, chemical, and engineering data to achieve national goals. NBS supports space systems, atmospheric and space research, and aeronautical programs.

NTIA is the principal communications adviser to the president. Its mission is to develop and coordinate executive branch policy in telecommunications and information. NTIA also is responsible for managing the radio spectrum assigned for federal use and providing technical assistance to other federal agencies.

Space Systems

Satellite Operations

Polar Orbiting Satellites. During 1982 *NOAA 6* and *NOAA 7* were the active polar-orbiting satellites operated by the National Earth Satellite Service (NESS). They are in sun-synchronous orbits of 810 and 850 kilometers and provide environmental observations of the entire earth four times each day. *NOAA 6* crosses the equator in a southward direction at about 7:30 a.m. local time, and *NOAA 7* crosses northward at 2:30 p.m. These satellites carry four primary instruments: the advanced very-high-resolution radiometer, the Tiros operational vertical sounder, the Argos data-collection and platform-location system, and the space environment monitor.

A new version of the spacecraft, the Advanced Tiros-N (ATN), has been developed to carry an increased payload. The first ATN satellite, NOAA-E (to become *NOAA 8* on launch in March 1983), will carry a search and rescue capability in addition to its primary instruments. Later flights will carry sensors to measure the earth's radiation budget and ozone.

Geostationary Satellites. GOES 4 and *5* were the operational satellites in NOAA's Geostationary Operational Environmental Satellite (GOES) system throughout most of 1982. In orbit at about 35 000 km above the equator, *GOES 4* is at 135° west longitude, and *GOES 5* is at 75° W. Both were equipped with the visible-infrared spin-scan radiometer (VISSR) atmospheric sounder (VAS), but, on 25 November 1982, the VAS failed on *GOES 4*. *GOES 1*, at 116° west longitude, was substituted for image taking. However, only the visible channel of the *GOES 1* VISSR is operable, and it has no VAS capability. The next geostationary satellite, GOES-F (*GOES 6* in orbit), is scheduled to be launched in April 1983.

The VAS provides traditional images of the earth's surface and cloud cover as well as new images that depict atmospheric temperatures and the water vapor content at various altitudes. The 12 infrared channels of the VAS can be used to derive temperature and moisture profiles in noncloudy areas at a much higher frequency than with radiosondes or polar-orbiting satellites. These satellites were being used in an operational demonstration program to determine the capability of the VAS. Results so far have been excellent, and efforts are under way to develop a ground system to use the VAS data to improve NOAA's operational weather analysis and forecasting. The failure of *GOES 4* created technical problems that temporarily terminated the VAS demonstration program, probably until after the launch of GOES-F. GOES satellites also carry a space environment monitor, a data-collection system, and a weather facsimile broadcast service. Other in-orbit spacecraft—*GOES 2* and *3*—remain on standby, providing limited operational support for weather facsimile and data collection. After more than seven years of service, *SMS 2*, one of the two original NASA prototype geostationary satellites, was deactivated 5 August 1982. It was boosted about 250 kilometers above its normal geostationary height to relieve the crowded geostationary orbit. During 1981, SMS 1 was deactivated in a similar manner.

Land Satellites. NOAA, authorized to manage an operational land satellite system based on the Landsat-D and -D′ satellites constructed by NASA, expects to assume operational responsibility for the first of these satellites early in 1983. NASA launched the Landsat-D (named *Landsat 4* after achieving orbit) on 16 July 1982 and completed the operational testing of the satellite in November. Since then, NASA has been proving the operational capability of the ground control and data preprocessing system at Goddard Space Flight Center (GSFC). During 1982, NOAA established a technical staff that will manage day-to-day *Landsat 4* operations at GSFC after NOAA assumes responsibility.

Landsat 4 carries one operational instrument, the multispectral scanner (MSS), and one research and development instrument, the thematic mapper (TM). The MSS measures reflected solar radiation over four bands of the visible and near-infrared wavelengths at 80-meter resolution, and the TM measures radiation over six bands of the visible and near-infrared wavelengths at 30-meter resolution and one band in the thermal-infrared wavelength region of 11 micrometers at 120-meter resolution. Data from these instruments became available for public use in October 1982. MSS data are available for most of the contiguous United States, Alaska, most of Central and South America, northern Europe and northwest Russia, Japan and near neighboring areas of Asia, and Australia. Limited, unscheduled TM data are available for the contiguous United States and Canada. In December, NOAA deployed tape recorders in India and Thailand to collect MSS data for those regions.

On 1 October 1982, NOAA assumed responsibility for producing and distributing Landsat data and data products, including those from *Landsat 1, 2* and *3*. NOAA contracted with the Department of Interior's Earth Resources Observation System (EROS) Data Center (EDC) for production and distribution. The products are sold to federal and other users to cover the coast of managing the overall Landsat program and operating and maintaining GSFC and EDC Landsat activities.

In 1982, NOAA hosted six public meetings on the operational Landsat program, to inform users of progress toward an operational system and identify their concerns. NOAA's new, higher price for MSS products was one topic of these presentations, to ensure that the prices are well known and to explain that they recover only the operating and maintenance costs, not capital costs. The main topic was definition of the MSS basic data set, which consists of pictures routinely collected by Landsat and is sold at regular prices. Requested special acquisitions require an added fee. TM products are provided to NASA researchers and sold to the public through the NOAA Landsat archive.

The Program Board on Civil Operational Land Remote Sensing from Space, established in 1981 by the Secretary of Comerce, provides interagency federal review of NOAA's Landsat activities. In 1982, the secretary established the Land Remote Sensing Satellite Advisory Committee to obtain nonfederal views on management and on transferring the program to the private sector. The committee is evaluating opinions; recommendations to the secretary are expected early in 1983.

Satellite Data Services

Data Distribution. Customers of the GOES-Tap system, which became operational in 1975, continued to increase. NESS completed modifications of its communication equipment at the Washington, Kansas City, and San Francisco Satellite Field Services Stations (SFSSs) to permit more GOES-Tap connections and plans to modify the New Orleans equipment. The original 50 Weather Service Forecast Office Taps increased by the end of 1982 to some 205 with a capability of expanding to 488 in the future.

Weather facsimile (WEFAX) broadcast schedules on GOES East and West satellites expanded, totaling 233 satellite image sectors and 24 weather charts daily. Known national and international WEFAX user stations increased to 176. In June, the National Weather Service (NWS) substituted WEFAX satellite image broadcasts for all satellite image data on the main United States to Europe facsimile circuit.

At the end of 1982, the GOES Data Collection System (DCS) totaled more than 3100 platforms (a 25-percent increase from 1981) operated by 61 national and international users. Eighteen direct-readout stations operationally received DCS data. A random-reporting operational test begun in February will continue for up to two years to determine if nonscheduled platform broadcasts will satisfy real-time data requirements and if random reporting can be managed along with scheduled broadcasts. The automatic monitoring system that evaluates each platform's messages and provides statistics for system management began operation in May.

NWS began operational demonstration in 1982 of a prototype service called Satellite Imagery Acquisition by Telephone Terminal. Small Weather Service Offices (WSO) that issue weather warnings can quickly receive high-resolution GOES satellite images for the cost of a 10-minute telephone toll call. To minimize costs, the number of offices receiving this service will be restricted to those in the hurricane-prone coastal sites and high-risk severe-weather/flash-flood inland locations.

The Environmental Data and Information Service (EDIS) archives U.S. environmental satellite data for the users, including film images and magnetic tapes collected by numerous satellites since early 1960. In addition to meteorologically oriented data, the archive contains information of interest to oceanographers, agronomists, geologists, hydrologists, and climatologists. These data are especially valuable to those engaged in research or monitoring conditions over areas for which no other observational data are available. EDIS also is developing a National Environmental Data Referral Service (NEDRES) to locate and describe environmental data files maintained by governmental agencies, private institutions, and businesses. This service will provide a readily accessible identification of what data exist, where, and how the data may be obtained. Data will span a wide range of scientific fields.

In late 1982, EDIS completed a feasibility study of the Geosynchronous Satellite Archival and Retrieval System (GARS). The system will collect full-resolution GOES digital data, store it, and produce statistical summaries and photographic and digital data. GARS should be operational by 1984.

Data Support. EDIS uses precipitation estimates from NOAA polar-orbiting and geostationary satellite images to support Agency for International Development (AID) disaster assistance. During 1982, EDIS provided assessments of the effects of weather variables on crops to 50 countries in Africa and also to Central and South America and Asia.

In addition to the meteorological satellite data archived at the National Climatic Center, the National Geophysical Data Center archives, analyzes, and publishes data on the solar-terrestrial and cryospheric environments recorded by NOAA, NASA, U.S. Navy and U.S. Air Force satellites in low-altitude, geostationary, geocentric, heliocentric, and Venusian orbits. These data are principally used in research, but also have applications in telecommunications, defense, transportation, power generation, exploration, meteorology, climatology, and hydrology.

Precipitating-electron data over the northern and southern auroral zones observed by polar-orbiting satellites were analyzed in support of the International Magnetospheric Study. Auroral boundaries and precipitation characteristics were determined to describe ionospheric and magnetospheric dynamics for magnetic substorms. The data also were used for the magnetospheric plasma motion model at Rice University. An EDIS-developed computer program identifying the equatorward boundary of the auroral oval from *Tiros N* and *NOAA 6* energetic particle measurements will support the tests of a new USAF over-the-horizon radar system.

The Kansas City Satellite Field Services Station continued to evaluate programs using the Central Storm Information System (CSIS) and the University of Wisconsin McIDAS System (man-computer interactive display system), incorporating information from the systems into daily operations. CSIS greatly increased the timeliness of GOES data and increased user interface on rapidly developing severe weather. Programs were written to "flag" meteorological conditions that precede mesoscale convective storms. Additional programs are being developed for forecasting heavy snow.

The Synoptic Analysis Branch of NESS provided satellite images and interpretations to the wire services, the news media, and the TV networks during the Falkland Islands hostilities. Satellite data were the only source of information available on weather in the Falkland Islands and vicinity.

GOES images gave weather support to the 1982 Space Shuttle flights. The NWS Spaceflight Meteorology Group at the Johnson Space Center used satellite data to monitor weather conditions for some preselected recovery sites.

NWS also supported the VAS assessment program, cooperating with the Space Science and Engineering Center (SSEC) at the University of Wisconsin in providing data for evaluation and special VAS products.

Until the demise of the VAS instrument on 25 November 1982, its images were provided four times daily from the western GOES satellite to NWS Forecast Offices and other meteorological agencies. Research during the past year has shown that the water vapor images reveal atmospheric circulation patterns, such as high-and-low pressure areas, fronts, and jet streams when clouds are absent. Clouds are necessary to detect these phenomena in visible and infrared images. For example, animation of water vapor satellite images up to seven days provides the San Francisco SFSS with a unique insight into large-scale atmospheric flow over the data-sparse areas of the Pacific Ocean. These images also permit better monitoring of moisture remaining—in the form of water vapor rather than clouds—from late-season eastern Pacific tropical storms and hurricanes that can cause precipitation over California, impairing such agricultural interests as raisin drying. VAS soundings over the Pacific Ocean may also greatly improve the 24- to 36-hour numerical weather forecast for the United States. Unlike the sounders on the polar-orbiting satellites, the VAS can sound the atmosphere over the Pacific Ocean at exactly the same time that conventional balloon soundings are obtained over the U.S. Simultaneous measurements greatly enhance the value of satellite observations. In two out of six tests, the Pacific soundings dramatically improved the 12- to 24-hour forecast. In no instance was the forecast degraded. More tests are planned for 1983.

Also during 1982, experimental VAS soundings from the *GOES 5* spacecraft were processed by NESS and University of Wisconsin scientists and disseminated to the National Severe Storms Forecast Center in Kansas City for evalution of their use in severe convective storm forecasting. The VAS measures upper air temperature and moisture every 80 km across the United States at two-hour intervals. Conventional upper-air balloon soundings are roughly 650 km apart and obtained only twice daily. Preliminary results were encouraging. The time variations of temperature and moisture observed by VAS in cloud-free areas provide a good estimate of where severe convective weather can be expected.

VAS data on atmospheric moisture distribution and circulation also are proving valuable for estimating the motion of tropical storms. The VAS moisture-profile data reveal both the low-level energy-source areas for tropical storm generation or dissipation and the upper-level vertical-motion patterns that support intensification or decay. Large-scale circulation patterns provided by the cloud motion observations and the thermal gradient observations in cloud-free areas provide a complete picture of the external forces governing storm movement.

NOAA's Prototype Regional Observing and Forecasting Service established a GOES direct-readout ground station in Boulder, Colorado. One of only three stations that can receive VAS data, it is used as part of the NOAA operational VAS assessment program. The service, evaluating the usefulness of VAS products in forecasting local weather at the Denver Weather Service Forecast Office, is testing techniques to combine satellite, radar, surface-meteorological-network, and ground-based sounding data to improve short-term (0- to 12-hour), local-scale (metropolitan area) forecasts. These applications are emphasizing severe storm and flash-flood warning.

Satellite Data Uses

Winds and Temperatures. A statistical evaluation of NOAA polar-orbiting satellite soundings indicate that they can be useful in global weather analysis and forecast models, as well as in analysis of specific situations. In the tropics, where conventional weather data are usually scarce, satellite data help monitor atmospheric circulation, particularly of hurricanes. In the eastern tropical Atlantic, the low-level jet stream also can be identified from satellite observations of vertical temperature distribution. In addition, moisture distribution, a key ingredient affecting growth and intensification of hurricanes, can be monitored.

During 1982, NESS began a new method for deriving high-level wind measurements. An interactive computer method, using the VISSR image registration and gridding system, controlled by a meteorologist, replaced the film-loop method used since 1973, saving $50 000 annually by eliminating photographic processing. In support of NESS research, University of Chicago scientists studied the mechanics of detecting and anticipating severe weather by seeking "signatures" of surface storms in satellite and radar images. The university participated in the Joint Airport Weather Studies of microbursts, the concentrated downdrafts that produce intense horizontal wind shear dangerous to aircraft during landings and takeoffs. NOAA's Wave Propagation Laboratory detected clear-air wind shears with pulsed doppler lidar at ranges of 15 km.

In 1982, NOAA's Wave Propagation Laboratory gathered aerosol backscatter statistics for 10-micrometer-wavelength, infrared-lidar (laser light detection and ranging) instruments. Values indicated that the proposed *Windsat* satellite, carrying a lidar, would recieve enough returned power to measure wind — if the Boulder backscatter values used in the experiment are representative of worldwide aerosols. In another study, thermal soundings from the *NOAA 6* microwave sounding unit combined with radiometric and radar data from the laboratory's ground-based profiler produced temperature profiles more accurate than from either system alone, except for a region at tropopause altitude.

NOAA polar-orbiting satellites are providing sea surface temperatures accurate within 0.75°C since the improved multiple-channel algorithms became operational in mid-November 1981. Corrections are being sought for aerosol contamination that caused low-altitude errors in the satellite-derived temperatures (as large as − 3°C) after the spring eruption of Mexico's El Chichon volcano.

Global Radiation. Nearly eight years of planetary radiation budget (1974–1982) estimates obtained from operational polar-orbiting satellites have been assembled. These data are used to monitor the earth's climate, to study the sensitivity of the radiation budget to cloudiness, and to understand the relationship of the radiation budget to the general atmospheric circulation. The data also are being used to study the impact of volcanic eruptions on climate.

Analysis of *Nimbus 7* data from the Earth Radiation Budget (ERB) experiment produced angular models of reflection and emission patterns from cloud and land surfaces, key elements in accurately estimating the radiation budget. Also, analysis of nearly four years of solar data from ERB yielded a mean solar constant of 1372.6 watts per square meter with a range of 6.2 watts per square meter. A continuous decline in the solar constant has averaged around 0.022 percent per year.

Environmental Warning. Vertical temperature profiles from the microwave sounding instruments on NOAA's polar-orbiting satellites help monitor the position and intensity of hurricanes. The microwave sounder penetrates most clouds to observe the high-altitude warm core of the hurricane. Statistical studies of 1981 hurricanes demonstrated that storm position can be estimated within 95 km, and that strength of maximum sustained surface winds can be estimated within 20 km per hour. This new capability could provide large cost savings in hurricane surveillance.

During 1982, the Miami Satellite Field Services Station continued to monitor Atlantic Ocean hurricanes providing the NWS National Hurricane Center satellite data on locations and maximum sustained winds for all hurricanes and other tropical cyclones every six hours. These data were often the only information available to forecasters for storms far at sea. Hurricanes were located with an average accuracy of 32 km and maximum sustained winds were estimated with an average accuracy of 18.5 km per hour. Center forecasters used the estimates with other information in formulating advisories for the public, marine, and military interests. The San Francisco station provided similar information for the eastern Pacific Ocean, the Honolulu station for the central Pacific Ocean, and NESS's Synoptic Analysis Branch for the western Pacific and Indian oceans.

NESS continued to use GOES images to estimate the amount of rainfall from thunderstorms, helping to forecast flash floods. During 1982, NESS identified four kinds of subtle heavy rainfall signatures from the images: synoptic-scale systems with a cyclonic circulation, single-clustered and multiclustered mesoscale convective systems with warm tops, large-scale overrunning systems with a large cloud area and no discernible heavy rainfall signature, and regenerative systems moving rapidly over the same area.

To improve flash-flood forecasting, an algorithm was developed to predict convective precipitation by tracking cloud tops in the GOES images; this algorithm includes a fully automated precipitation estimation technique to help forecast expected accumulation. Another improvement, the interactive flash-flood analyzer (IFFA), was delivered to NESS in June 1982; software development and system integration is now in progress, with operation scheduled by 1 March 1983. The IFFA will improve timeliness and accuracy of satellite-based flash-flood products, and it will be able to disseminate them to NWS and NESS field offices and other users simultaneously.

During 1982, operational flash-flood support to the NWS Western Gulf River Forecast Center (WGRFC), Fort Worth, supplied satellite-based rainfall estimates in digital format for models forecasting the level of rivers. Effectiveness of the data will be assessed during 1983. The San Francisco station improved the timeliness of satellite quantitative precipitation estimates by direct electronic input of satellite data into the "Satellite Information Display System." The estimates were rapidly distributed to users through the NWS automation of field operations and services system. San Francisco is experimenting with graphic displays of precipitation estimates for easier field use.

Introduction of combined visible-infrared images to replace alternating visible and infrared data improved monitoring of convection in the NWS Western Region. The high-resolution pictures switch from the visible to infrared where cloud tops are colder than −42°C, for more consistent observation. NOAA's Office of Weather Research and Modification used GOES digital infrared images to investigate the diurnal variation of rainfall over the tropical and subtropical Pacific Ocean and to study the feasibility of estimating rainfall from winter storms. Investigating large-area effects of cloud seeding, it found that—over a 330-km radius surrounding the seeding target area—the seeded days produced more rain in the target and downwind than did the no-seed days.

Satellite images are used to locate the 5°C isotherm and pockets of lower temperatures in the Alaskan waters. The 5°C isotherm is one of the critical parameters for determining expected severity of icing. Superstructure icing is a major problem for vessels of all sizes. Special ice images provided to the NWS forecast offices and the Joint Navy-NOAA Ice Center at Suitland, Maryland, are used by various agencies in the preparation of ice analyses, forecasts, and special operations and rescue efforts. Oil companies use the products to monitor ice conditions during shipping and drilling operations.

Time-lapse film loops of high-resolution satellite images give a better understanding of the behavior of sea fog, a hazard to offshore drilling and to boating. More accurate short-range forecasts of sea fog formation and dissipation are expected to result from empirical studies relating the changes in sea fog to changes in surface winds and sea surface temperatures observed from satellite data.

During 1982, NESS expanded its volcano reporting activities. In addition to providing volcanic data to the Smithsonian Scientific Events Alert Network (SSEAN), NESS sent information on major volcanic eruption to meteorological offices in areas affected by volcanic ash and dust.

NOAA 7 and GOES satellites detected and monitored the four large eruptions of El Chichon volcano in Mexico in late March and early April, reporting information to SSEAN. The last of these eruptions produced a large stratospheric dust cloud that took three weeks to circle the earth and covered a latitude belt between 5°N and 30°N. Also, *NOAA 7* and the Japanese GMS satellites monitored the multiple eruptions of Galunggung volcano in Java between April and August 1982. The Air Lines Pilot Association has expressed interest in using satellite data for rerouting air traffic around eruptions. In addition, these satellites were the first to detect the eruptions of Loputan volcano in Indonesia on 26 and 27 August.

Oceanography. NOAA's Pacific Marine Environmental Laboratory analyzed altimetry data from *Seasat* (the NASA's ocean-sensing satellite operated in 1978) using path-length corrections from the Jet Propulsion Laboratory. Surface current velocities, short period changes in position of Gulf Stream axis, and warm core eddies northeast of Cape Hatteras were evident in altimeter velocity profiles and also in coincident infrared data. The laboratory also is developing algorithms for measuring particulate matter distributions in the ocean from surface color information. Finite depth theory for nonlinear internal waves has been developed to explain observations of large-amplitude waves (solitons) in the Sulu Sea during a 1980 field experiment. Internal waves have been observed in numerous satellite images. The theory was found to be in good quantitative agreement with the images.

New Orleans and Washington SFSSs are now producing thermal analyses of the Gulf of Mexico and Northwest Atlantic Sea Surface. The charts aid fishermen in pinpointing the thermal gradients where fish tend to locate, saving costs and providing overall economic benefits to commercial marine transportation and recreational boaters.

Hydrology. EDIS conducted a study to evaluate the data from a snow/cloud-discriminator sensor system flown on a DMSP satellite in 1979. Distinction between snow and clouds from satellite photos has long been a problem to users, impeding snow-melt and runoff forecasts, the monitoring of global snowcover, and the determination of distribution and frequency of clouds on varying spatial and temporal scales. EDIS completed a digitized archive of Southern Hemisphere snowcover for 1974–1980, using satellite data—the first time Southern Hemisphere snowcover has been measured with any accuracy.

Melting snow is the source of 70 percent of the water in the western United States. Since 1974, NESS has monitored snowcover for 30 watersheds in this region. In 1982, this snow-mapping technology was transferred to users and NESS field offices in the central and western United States, including the Salt River Project, which assumed snow-mapping duties for the river basins of central Arizona. A digital snow-mapping technique, using geostationary satellite data, was started at the Kansas City SFSS and covered basins in Montana, Wyoming, Colorado, and Nevada. Specially processed polar-orbiting satellite data over the Sierra Nevada Mountains permitted the California State Department of Water Resources to monitor the mountain snowpacks above the fertile Sacramento and San Joaquin Valleys. The San Francisco SFSS began monitoring snowpacks in Oregon, Idaho, and selected areas of British Columbia in November.

In late 1982, EDIS began a project to evaluate data from the *Nimbus 7* scanning, multichannel, microwave radiometer (SMMR). The objectives are to develop useful snow and ice information products, inform Goddard Space Flight Center of difficulties in using the products and of suggestions for improvements, and verify selected data with "ground truth" data from other sources.

Agriculture. NESS continued to develop products for agriculture from weather satellite data in the Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing (AgRISTARS), a program to develop techniques for monitoring extent and condition of major crops worldwide. In this cooperative effort, the U.S. Department of Agriculture (USDA) is the lead agency, with NASA providing research and special products from Landsat data, the Department of the Interior providing routine Landsat data, and NOAA providing yield models and special products from its operational satellite data. Special products include daily estimates of precipitation, insolation, maximum and minimum temperature, vegetation index, and snowcover.

During 1982 for example, EDIS continued to acquire and evaluate candidate yield models for wheat, barley, corn, and soybeans. Testing also began on advanced-simulation crop models that attempt to describe the physical and biological processes of conditions affecting crop production. Development of techniques for more accurate forecasts of domestic and foreign commodity production in the major grain-producing countries of the world are project objectives.

EDIS and NESS developed techniques that used data from the *NOAA 6* and *7* advanced, very-high-resolution radiometer (AVHRR) to assess crop stress and areas of excess water. Meteorological satellite data offer a major advantage in frequency and time of global coverage. Meteorological satellites can cover the same area twice daily; Landsat covers the same ground once every 18 days. The high-resolution satellite data are now used operationally by the USDA to monitor crop growth in primary grain regions worldwide, by the United Nations Food and Agriculture Organizations to monitor desert-locust breeding habitats, by the government of Senegal to monitor the availability of vegetation for grazing animals, and by the U.S. Bureau of Land Management (BLM) to monitor the condition of foliage in fire-prone districts. In May 1982, NESS began producing weekly composite vegetation-index images of the Northern and Southern Hemispheres. The reduced-resolution AVHRR data indicate possible climatic changes as well as regional phenomena such as droughts, desert creep, and deforestation. In August, the San Francisco SFSS started producing twice-weekly pictures of vegetative index over the agricultural areas of California, Oregon, and Washington.

NOAA in 1982 began producing a global mapped-vegetation index that is a measure of density and vigor of vegetation. Production of insolation estimates for the United States continued and coverage was extended to Mexico, Argentina, and Brazil. Three satellite-derived visible and infrared precipitation algorithms were identified for potential use. Plans are to test these algorithms and, where possible, to combine the best aspects of each for operational demonstration in 1984.

NESS began producing maps in May 1982 of incoming solar radiation for the entire United States, printing insolation values for 1° squares from GOES satellite data. These data are being evaluated by USDA for crop field models, by NWS for evapotranspiration models, and by the U.S. Forest Service for fire weather models. Production of insolation estimates also were extended to Mexico, Argentina, and Brazil. A NESS soil-moisture gauge, relocated at University of Minnesota Agriculture Research Station in Lamberton, Minnesota, will provide ground data for comparison with NASA and USDA microwave data obtained by aircraft overflights starting in late 1983. The overflights are part of a larger program, called Plan of Research for Integrated Soil Moisture Studies (PRISMS), to develop a remotely sensed technique for estimating soil moisture.

Fisheries. Satellite-derived ocean data have many fisheries applications. The Southeast Fisheries Center demonstrated that satellite communications could speed up distribution of information to users during the state-federal Southeast Area Mapping Program (SEAMAP). NOAA, the National Marine Fisheries Service, and charter, state, and Mexican research vessels participated in the program. Information on bottom fish and shrimp size was transmitted through the *ATS 3* satellite and the NOAA ARGOS data-collection system to shore stations for distribution to fishermen, fishing associations, state fishery managers, researchers, and federal investigators.

The Fisheries Service's satellite-image processor in Slidell, Louisanna, is now fully operational. In 1982, it was used to evaluate Landsat data for monitoring changes in coastal wetland ecosystems. This evaluation is being conducted jointly with the U.S. Fish and Wildlife Service and the state of Louisiana. A second study demonstrated the feasibility of mapping shallow water corals from Landsat data.

Subtle ecological effects of hurricanes were studied through an analysis of coastal-zone color scanner (CZCS) data. Two major 1979 hurricanes, Frederic and Henri, led to significant upwelling along the Mexican coast, causing a major phytoplankton bloom observed by the CZCS on September 29 and October 3. Ocean color data also were used with thermal data to map distribution patterns of bluefin tuna in the Gulf of Mexico. This mapping has been highly successful.

An opportunity to apply satellite thermal data to an environmental event potentially damaging to coastal shrimp resources in the northern Gulf of Mexico occured during summer SEAMAP surveys. A large area of ocean bottom water off the coast of Louisiana was found to have low oxygen levels. Evaluation of thermal data showed a high correlation between areas of low oxygen and pools of unusually warm surface waters. These warm surface waters cause thermal stratification that, when coupled with high organic loads, lower the oxygen content.

The Northeast Fisheries Center continued the Coastal Habitat Assessment Research and Mensuration (CHARM) Program. Using Landsat multispectral scanner data, CHARM quantifies changes in productivity, biomass, and area of principal coastal-zone vegetation from North Carolina to Maine. Phase 1 of the program—to determine the acreage of wetlands, with the kinds of vegetation—has been completed. The center participated in three field experiments of the National Science Foundation warm-core-ring investigation, examining physical, chemical, and biological processes in the interaction of warm-core rings with Gulf Stream waters and the refinement of remote-sensing technology used in marine sciences. Support included near-real time satellite infrared images. Detailed analyses of the data will be made in 1983.

Scientists at the Southwest Fisheries Center used CZCS ocean color data and *NOAA 6* temperature measurements to define the spawning habitat of the northern anchovy and predict distribution and migration. Using similar satellite data and fishery logbook data, center scientists also demonstrated that albacore tuna aggregate near ocean color boundaries, preferring warm, clear, oceanic waters and avoiding cool, turbid coastal waters. Satellite color and temperature data and acoustic devices attached to free swimming albacore identified water clarity for feeding, rather than thermal physiology, as previously believed, as a probable cause of tuna aggregation near oceanfronts.

Other Uses of Satellites

International Activities

France provides the ARGOS data-collection system and the United Kingdom the stratospheric sounding unit for the NOAA polar satellites. The agreement under which the French National Center for Space Studies, NASA, and NOAA cooperate in satellite data collection is being amended to reflect interest in continuing this program. An agreement with the United Kingdom Meteorological Office on cooperation in stratospheric soundings also is being extended.

NOAA participated in U.S. preparations for the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE '82), held in Vienna 9-21 August 1982, and contributed displays depicting applications of land and environmental remote-sensing data. The agency also began negotiations with foreign countries for direct ground-station reception of Landsat data after the

Landsat system is transferred from NASA to NOAA in February 1983.

More than 120 countries receive images and digital data directly from satellites operated by NESS. Low-resolution images from polar-orbiting satellites are received at 890 locations, and high-resolution images from the same satellites are received at 76 sites in 32 countries. Both polar-orbiting and geostationary satellites provide data-collection services—the geostationary regionally and the polar orbiter globally. In addition, the geostationary satellites broadcast weather facsimile data and high-resolution images for direct-readout stations within communication range.

The National Climate Program Office is coordinating U.S. participation in the International Satellite Cloud Climatology Project (ISCCP), scheduled to begin in mid-1983. The ISCCP is the first project of the World Climate Research Program, under the joint sponsorship of the World Meteorological Organization and the International Council of Scientific Unions. ISCCP will take advantage of global coverage by five geostationary satellites and the NOAA and Meteor polar orbiters of the U.S. and U.S.S.R. The geostationary satellites were to be the United States *GOES 4* and *5*, the Japanese Geostationary Meteorological Satellite *GMS*, the Indian Satellite *Insat 1A*, and the European Meteorological Satellite *Meteosat 2* of the European Space Agency. However, *Insat 1A* and *GOES 4* are no longer operational. GOES-F (*GOES 6* after launch in April 1983), will replace *GOES 4*, and India is planning to launch *Insat 1B* at a later date. These satellites will gather five years of visible and infrared radiance data to produce a calibrated global data set for the international scientific community. Participating U.S. agencies are NOAA, NASA, NSF, DOE, and DoD.

Training

During 1982, the NESS Applications Laboratory provided training in satellite image interpretation to about 500 persons. Seven field and two local classes each were conducted for 135 NWS and 185 Department of Defense weather personnel. Also, 29 visitors from 14 foreign countries were trained in such subjects as general satellite meteorology, tropical storm interpretation, and precipitation estimation. Four workshops were held in 3 foreign countries, with a total of 151 trainees from 14 countries.

Application of Space Technology to Geodesy and Geodynamics

The National Ocean Survey (NOS) and NASA have agreed that NOS will assume complete responsibility for observations at stations of the National Crustal Motion Network by 1985. NOS will maintain the network, using mobile very-long-baseline interferometry and Global Positioning System equipment to increase the precision of geodetic measurements over continental distances and as a service to scientists and engineers working in geodynamics.

Studies of the proposed gravity satellite—GRAVSAT—system indicate that the concept of determining the global gravity field of the earth by observing the relative motion of a pair of satellites close to each other is sound. GRAVSAT has the potential to improve knowledge of the earth's gravity field by 10 times or more, at scales of a few hundred kilometers or greater.

The National Bureau of Standards (NBS) completed studies showing that the orbits of DoD's NAVSTAR Global Positioning System (GPS) satellites can be determined to within 20 centimeters for the horizontal coordinates when all 18 satellites are in operation. The studies also showed that the GPS signals could be received by the proposed Topographic Experiment (TOPEX) altimeter satellite and used to determine its radial coordinate with a 3-cm accuracy. The accurate measurement of the TOPEX orbit will permit full use of the altimeter results to determine small variations in the height of the sea surface.

Data Buoys

During 1982, NOAA obtained surface meteorological data from 25 ocean-moored buoys for weather analysis and forecasting. The data were transmitted through GOES satellites synoptically, and the ARGOS data-collection and platform-location systems on NOAA polar-orbiting satellites monitored the buoys to detect mooring failures. Prototype drifting buoys, measuring a simple set of surface meteorological parameters and subsurface temperatures, were tested in the northeast Pacific Ocean for application in providing information in data-sparse regions for weather analysis and forecasting.

Satellite Time Service

NBS has devised a technique in which simultaneous viewing of the same GPS satellite can provide extremely precise time transfer. With GPS receiving equipment developed by NBS, time-transfer precisions in the nanosecond range have been demonstrated between the NBS laboratories in Boulder and the United States Naval Observatory in Washington, D.C. This equipment is now being installed at NASA sites in Spain and Australia to support tracking of deep space probes. The NBS system promises improved synchronization at a cost equal to or lower than that of older timing systems.

NBS also is part of a NASA-sponsored team to provide highly accurate, worldwide, time and frequency transfer by integrating the latest technologies into the Space Shuttle. Systems under consideration include a space-qualified hydrogen maser in the Shuttle and both a laser-ranging and a microwave doppler-cancellation system at ground timing centers. In support of Jet Propulsion Laboratory's effort to improve the reliability of hydrogen masers for the Deep Space Network, NBS developed a new source of ultrapure hydrogen. The new source occupies less than half the volume of a conventional storage bottle and also continuously purifies the hydrogen.

Studies of Low-Gravity Effects

Materials Processing in Space. A major feature of materials processing in space is an expected great reduction in gravity-driven convection. Sufficient reduction in convective stirring could produce improved materials. To predict this influence, NBS has measured convective effects of temperature and impurity gradients during freezing and surface-tension gradients that could produce a further source of convection.

Test of Theory of Relativity. NBS has been collaborating on NASA's Gravity Probe B experiment to test the theory of general relativity by measuring the precession of a spinning sphere that is orbiting the earth. Because the predicted relativistic precession is extremely small, it is essential that residual torque on the spinning sphere also be small. Superconductive support electrodes have been used in earth-based models to reduce eddy-current heating. Analysis at NBS in 1982 showed that nonsuperconductive electrodes should probably be used in the flight model, since the magnetic torque from each superconductive electrode exceeds the design goal for residual torque by three orders of magnitude.

Dynamic Thermophysical Measurements in Space. NBS is developing techniques for the dynamic (subsecond) measurement of selected thermophysical properties, such as heat capacity, heat of fusion, and electrical resistivity of solids and liquids at temperatures above 2000 kelvins. Experiments will be performed in a near-zero-gravity environment in space, where it may be possible to sustain a liquid-column specimen for the duration of the brief experiment and obtain, for the first time, accurate data on thermophysical properties above the melting point of high melting substances. A preliminary system for testing the stability of the liquid specimen in near-zero gravity is being tested in preparation for flight testing in 1983.

Immissible Liquid Droplets. The effect of diminished gravity on nucleation in the liquid-solid front of a growing metallic crystal was studied. The study led to the design of a self-contained controllable heat value that would permit many of the control, feedback, and amplification functions performed by triodes in electrical circuits to be duplicated by a temperature-controlled thermal triode.

Satellite Communications. The National Telecommunications and Information Administration (NTIA) is responsible for developing the federal government's proposals for the International Telecommunications Union (ITU), the United Nations agency that establishes and administers international regulations concerning the use of the radio spectrum, including its use by spacecraft. In preparation for the ITU's 1983 Regional Administrative Radio Conference on broadcasting-satellite service, NTIA participated in the second Conference Preparatory Meeting and Software Panel of Experts. Also, through its Institute for Telecommunication Sciences, NTIA performed studies to assist in determining orbit-spectrum capacity and how it might be shared with other Western Hemisphere countries. NTIA continues to lead government agencies in the preparations for the 1985 and 1987 World Administrative Radio Conferences for planning space services. Relevant to this effort, the ITU completed initial work in the development of a computer-based model for analyzing orbit and spectrum use.

NTIA also registers the frequencies used by government satellites with the ITU. In this manner, the government protects its spectrum use and coordinates proposed operations. NTIA also assigns frequencies for operating the satellite systems.

In cooperation with the Department of State and the Federal Communications Commission, NTIA participates in overseeing the Communications Satellite Corporation's activities in the International Telecommunications Satellite Organization (INTELSAT) and the International Maritime Satellite Organization (INMARSAT). In February 1982, INMARSAT began operations using Marisat spacecraft serving more than 1000 ship and land stations in the marine environment; ship stations in the system are increasing at a rate of almost 5 percent per month. In addition, INTELSAT's annual growth in revenues and circuit use continued at more than 24 percent; its capital ceiling was increased to $2.3 billion; orders were placed for six Intelsat V-A spacecraft, which will each have about 25 percent greater capacity than the Intelsat V. The first five Intelsat V spacecraft have been launched—one in 1980, two in 1981, and two in 1982.

Space Support Activities

Warnings and Forecasts.

The Space Environment Service Center, operated by NOAA and USAF, is the national and world warning agency for solar-terrestrial disturbances that affect men and equipment operating in the upper atmosphere and space environment. The center provided forecasts and warnings for Space Shuttle operations, including specific support to solar physics payloads on STS 3 that observed polarized hard x-ray emission from solar flares. Radiation forecasts for launch and in-orbit operation, including crew protection, were also provided.

Using data from one of the International Sun-Earth Explorer satellites (*ISEE 3*), the center provided a warning of the beginning and end of a major geomagnetic storm with such accuracy that the operators of a series of defense navigation satellites were able to compensate for storm-induced atmospheric heating. By accounting for varying atmospheric drag on the satellites, the operators kept the positional error for the satellites within prescribed operating tolerances. Until this success, the usual effects of large storms was to cause positional errors that exceeded planned tolerances.

Measurement and Calibration Services

Spectrometer Design. Operating the large spectrometer-calibration chamber and associated radiometric beam line at its Synchrotron Ultraviolet Radiation Facility (SURF), NBS calibrated rocket payloads from the Naval Research Laboratory, the Laboratory for Atmospheric and Space Physics, and Goddard Space Flight Center and the stellar spectrometer of the fine-pointing telescope from Johns Hopkins University. NBS also calibrated the Naval Research Laboratory's Space Shuttle experiment—the solar-ultraviolet spectral-irradiance monitor (SUSIM)—both before and after its flight in early 1982. In addition, a deuterium lamp calibrated by NBS flew on SUSIM as an inflight ultraviolet calibration source.

Instrument Fabrication. NBS is providing machined parts for NASA's neutral ion mass spectrometer for the *Galileo* probe (flight unit). Machining requires very close tolerances in size, weight, and machine finishes. Most of these parts are machined from materials such as titanium, stainless steel, and glass ceramics.

Electromagnetic Radiation Detectors. NBS is investigating the fundamental physics of small-area superconductive tunnel junctions, which, used as heterodyne receivers, have recently been shown to be extremely sensitive detectors of electromagnetic radiation. The thin-film devices of low-transition temperature superconductors are fabricated in an NBS facility, cooled below the transition temperature with dilution refrigerators, and tested at microwave frequencies.

Electromagnetic E-Field Meter. A highly sensitive electromagnetic E-field meter was supplied to NASA within 24 hours of request, to meet a possible emergency aboard the Space Shuttle before its second flight. The instrument was designed to measure electromagnetic interference from onboard radar inside the crew quarters.

Cryogenic Flowmeter. Thrust control on the Space Shuttle main engines requires measurement of the flow rate of liquid oxygen to them. The original turbine flowmeter has been found unsatisfactory, and NASA is supporting an NBS investigation of a vortex shedding flowmeter as a possible replacement. The meter must function in liquid oxygen moving 10 times the normal design velocity of the flowmeter but with a pressure drop around 68 atmospheres (100 psi). The flowmeter also may be subjected to swirl. Flow tests to date—using a 3.8-centimeter, commercially manufactured flowmeter as a starting point—indicate that the flow velocity and pressure drop requirement can be achieved.

Aerospace Systems

Artificial Intelligence, Robotics, and Computer Vision. To enable NASA to make informed decisions on research and applications in artificial intelligence, robotics, and computer vision, NBS is preparing reports on basic techniques, state-of-the-art techniques, research requirements, research under way, participants and their funding, and a 5- to 10-year technology forecast.

Pulse-Tube Refrigeration. A pulse-tube refrigerator contains only one moving part and can provide refrigeration down to at least 100 kelvins. An experimental, theoretical study is identifying sources of inefficiency and the effect of various parameters such as geometry and frequency of operation. Since the refrigerator has the potential for high reliability, it would be useful for operation in satellites.

Combustion of Metals. A number of times during development of the Space Shuttle's main engines—which use high-pressure oxygen and hydrogen as propellants—metallic materials of the oxygen system ignited, causing their destruction. NBS is seeking to determine the conditions under which metals can be expected to ignite, so they can be avoided in the future.

Space and Atmospheric Research

Solar Activity

Solar Flares. NBS continued to work with the *Solar Maximum Mission* team in analyzing data from solar flares. The data were taken with flat and curved crystal spectrometers whose radiometric and diffraction properties were measured at NBS. The data are being used to infer the properties of the hot flaring plasma and the mechanics by which this plasma cools.

Solar Convection. The properties of solar convection and the associated transport of mechanical energy are being investigated, with observations of steady and oscillatory velocities complemented by theoretical studies of both anelastic model convection and acoustic-gravity waves. Data obtained with the ultraviolet spectrometer and polarimeter experiments on the *Solar Maximum Mission* satellite suggest that the large-scale steady flows observed in the sun's chromosphere-corona transition region are a combination of the overshooting of convection motions from below and the downflow of coronal material along magnetic-field lines. Recent observations using the diode-array instrument at Sacramento Peak Observatory indicate that the five-minute oscillations can be used to probe subphotospheric cellular structures. Theoretical models of solar convection show that a single large-scale mode can transport nearly the full solar flux over most of the convection zone.

Interplanetary Physics. NOAA's Space Environment Laboratory (SEL) is constructing a computer simulation model that describes the flow of mass, momentum, and energy from the sun to the earth's magnetosphere. The model incorporates the coupling of the interplanetary magnetic field (IMF) to the outward-flowing solar wind plasma. Computer simulation of the sun's activity can be used to predict and evaluate the evolution of interplanetary disturbances that originate at the solar surface and subsequently reach the earth's orbit. The magnetohydrodynamic model is being tested by incorporating solar observations in the model and by direct comparison of the predictions with spacecraft such as *ISEE 3*.

Magnetospheric Physics. SEL continued analysis of magnetospheric charged-particle data from detectors aboard the operational NOAA and GOES satellites, as well as data from comprehensive particle detectors aboard the NASA ISEE satellites. The studies seek understanding of magnetospheric boundary, particle energization, and transport processes, which are keys to understanding the coupling of energy from the solar wind to the earth's atmosphere and the consequent magnetic and ionospheric disturbances that can seriously compromise communications, navigation, information, and power transfer systems.

Planetary Atmospheres. NBS continued laboratory investigations of the rate constants, mechanisms, and photochemistry of chemicals prevalent in the atmospheres of the planets and their satellites. New chemicals predicted in these atmospheres were subsequently observed. Experimentally, NBS remeasured and confirmed the rate constants, at ambient temperatures, for reaction of ethynyl with hydrocarbons. Continuing to characterize the far-infrared spectra of the gaseous constituents of the outer planets, NBS has shown that some of these spectra can be accurately represented by a semi-empirical line shape. An important result of this work is the analytical representation of the rotation translational spectrum of hydrogen, which will make it possible to calculate the spectrum at a variety of temperatures and over a very broad frequency.

Atomic Data. NBS compiles critical data on atomic energy levels for predicting and interpreting spectra of astrophysical interest. In 1982, NBS continued to compile spectra for the element silicon by extending the data from the 6th ionization stage through the 13th. It also was assembling all the data for potassium through nickel into a single compilation. New data have been added as they appear in the literature. When complete, the compilation will contain 235 spectra for the elements cited and will permit improved assignment of wavelengths for spectral lines observed in solar flares, hot stars, and other astronomical plasmas.

Stellar Atmosphere. During 1982, NBS scientists used the International Ultraviolet Explorer *IUE* and the *Einstein* X-ray Observatory (*HEAO 2*) satellites to study which stars have hot outer atmospheres like the sun and which have cool outer atmospheres. They also used those satellites to study close binary stars with bright active regions and to study stellar flares. The observations indicate that magnetic fields play important roles in stellar atmospheres. They also have found evidence for downflows in a number of active chromosphere stars.

Atmospheric Chemistry

Earth's Atmosphere. In cooperation with NASA and the Chemical Manufacturers Association, NBS conducts gas kinetics and mechanistic investigations of selected atmospheric reactions of importance in modeling catalytic cycles that control stratospheric ozone. In particular, NBS has recently completed measurements on two reaction systems that help define the photochemical lifetime of chlorine atoms in the stratosphere. Thus NBS program on spectroscopic standards and tunable laser spectroscopy also supports NASA's upper atmospheric research. Direct frequency measurements of molecular calibration lines have provided secondary frequency and wavelength standards in the infrared two to three orders of magnitude more accurate than the previous measurements made with wavelength techniques.

Determination of the dependence on temperature of the ozone ultraviolet-absorption cross-section is of particular importance to accurate stratospheric measurements and modeling. NBS has recently completed measurements over the wavelength region of 250 to 340 nanometers at temperatures of 295, 243, and 228 kelvins. Measurements have been started at 273 K and will be completed during the coming year. NBS also has completed detailed measurements of the temperature variation from 210 to 295 K of the ozone cross-section at the wavelengths of the eight principal Dobson bands, used for ground-based observations of the total column density of ozone. Scientists at NOAA and Environment Canada have concluded that these new cross-sections substantially resolve inconsistencies previously observed.

NOAA's Aeronomy Laboratory is analyzing data from the Solar Mesophere Explorer (*SME*) satellite—in particular stratospheric profiles of nitrogen dioxide (NO_2), which provide a global picture of the component that at present is most important in controlling the amount of ozone present. Both global abundance of ozone and its perturbation by solar proton bursts have been sucessfully modeled. The laboratory also is investigating an unanticipated feature of the satellite—its demonstrated ability to measure lower tropospheric NO_2 pollution.

Aeronautical Programs

Aeronautical Charting

The National Ocean Survey (NOS), which produces aeronautical charts and chart-related products for navigation in U.S. air space, has reconstructed the Sectional Aeronautical Chart series to improve reliability and accuracy. Designed for use by low- and medium-speed aircraft, these charts are used by pilots flying under visual flight rules. NOS also improved the design concept for computer-assisted cartographic techniques to produce aeronautical charts. The improved techniques permit NOS to respond more rapidly to new technology developed by the aircraft industry.

Weather Research

NOAA's National Severe Storms Laboratory in Norman, Oklahoma, continued to study weather hazards to aviation and Space Shuttle flights. Turbulence, hail, wind shear, and lightning are being investigated by a network of lightning detectors, dual-doppler radars, weather radar, surface observations, rawinsondes, a 444-meter meteorologically instrumented TV-tower, and aircraft obervations. Lightning characteristics and locations are used to define operating procedures for the Shuttle and to evaluate effects on solid-state airborne electronic equipment. Ground-based doppler radar observations in a joint program with the Federal Aviation Administration validate prototype radars for turbulence detection scheduled for use on commercial airliners. In a joint program with the multiagency Next-Generation Radar (NEXRAD) Joint Systems Program Office, techniques are being developed to detect gust fronts, wind shear, tornadoes, and turbulence for improved guidance of aircraft.

Structures and Materials

Fiber-Reinforced Composites. A major source of concern in the use of fiber-reinforced composites for aircraft bodies is reduction in strength by cracks developing in the polymeric material binding the fibers together. In a cooperative program, NBS, NASA's Langley Research Center, and several industrial suppliers are developing a way to measure the resistance of polymeric materials to crack growth. During the past year, basic guidelines for this measurement technique have been developed for the brittle polymeric resins now in use. Future work will investigate the effectiveness of the technique and extend it to polymers being developed to be more resistant to cracks.

Surface Microtopography of Wind-Tunnel Models. NBS is developing a procedure for characterizing the surface topography of models to be used in NASA's National Transonic Facility (NTF). Surface texture will play a significant role in testing, since the aerodynamic boundary-layer thickness at high air speeds of the NTF will be in the submicrometer range. To provide a technique convenient to use as well as suitable for measuring surfaces with large curvature, NBS has constructed a light-scattering system. During 1982, it made a detailed comparsion of stylus profilometry with light-scattering measurements of surface topography.

Thin Film Thermocouple. The NASA-sponsored advanced thin-film thermocouple program focuses on measuring turbine airfoil temperatures in commercial and military aircraft gas turbines. A new technology in which thin-film thermocouples are sputtered directly on a turbine airfoil is being developed. The new sensors permit the measurement of surface temperatures on thin-walled, air-cooled turbine airfoils without perturbing the airflow around the surface or the heat flow to the surface. The measurements provide new information on heat transfer to the airfoil and airfoil cooling and structural design. NBS is examining methods of fabricating durable, multilayer, sensor structures on turbine airfoil superalloys and is evaluating the accuracy of the sensors.

Department of Energy

The United States Department of Energy (DOE) has statutory responsibility for the research and development of nuclear-electric power systems for the nation's space programs. Nuclear systems developed by DOE and its predecessor agencies have provided electric power for many NASA and Department of Defense missions since the early 1960s. Nuclear power provided the electrical energy for NASA's Pioneer, Viking, and Voyager missions and DoD's Lincoln Experimental Satellites (*LES 8* and *9*), as well as earlier earth orbital and lunar missions. Since 1980, DOE has been developing technology of lightweight, safe, nuclear reactors for higher power requirements of future space missions, at 100 kilowatts and above. In 1982, DOE began testing simulated radioisotope thermoelectric generators (RTGs) for the NASA *Galileo* mission and the International Solar Polar Mission.

The compact size, light weight, and long life of nuclear-powered electric generators make possible operation of the sensing, analytical, and communication systems of spacecraft, satellites, and other remotely located devices for long periods without external sources of energy. Nuclear research and development in the DOE-sponsored space and special applications program delivers environmentally acceptable, operationally safe, compact, and technically qualified energy systems to federal agencies for earth-orbital and interplanetary space missions, as well as for other special-purpose applications.

Space Applications of Nuclear Power

The space and special applications program has evolved from efforts to develop nuclear power for aerospace applications since the early 1950s. The program now consists of three projects: (1) static outerplanetary radioisotope thermoelectric generator (RTG) project, developing RTGs for *Galileo* and the International Solar Polar Mission; (2) space reactor technology program (SP-100), an advanced technology readiness program; and (3) a terrestrial RTG project.

Radioisotope Thermoelectric Generators

During 1982, components for engineering, qualification, and two flight-unit general-purpose heat-source RTGs (GPHS-RTGs) were fabricated, continuing the development of an advanced silicon-germanium generator for NASA's *Galileo* and the International Solar Polar Mission in 1986. Thermal and dynamic testing of the engineering unit began. The *Galileo* mission is to send an orbiter spacecraft with atmospheric probe to Jupiter. The solar polar mission will collect scientific data on the sun and solar wind from high heliographic latitudes. The 55.5-kilogram GPHS-RTG is designed to provide a minimum 285 watts of electrical power, with a fuel loading of 4410 thermal watts.

Production included fuel, iridium, and graphite components. Key components of the RTG Assembly and Testing Facility were completed in 1981. Multihundred-watt-heat-source production and component fabrication of the *Galileo* radioisotope heater units also were completed in 1981.

The Savannah River Plant supplied encapsualted isotope hardware for the program. The Mound Facility will assemble the isotope-fueled modules into a heat source, load the heat source into the thermoelectric converter, and test the fueled power unit to qualification and flight acceptance levels. Fueling and testing of the qualification converter and the first flight converter are planned for 1983 and 1984.

Advances in Supporting Technology

During 1982, DOE began fabricating and performance-testing two modular isotopic-thermoelectric-generator (MITG) test modules. Data from these tests will help determine further development of the new RTG concept, which takes advantage of new materials, fabrication techniques, and design to analyze the potential for a more advanced, much lighter generator for future space missions. Except for its end sections, the generator consists of a number of identical slices of a standard design, each producing about 24 watts of electricity at 28 volts. The basic design appears adaptable to many uses, since the power output can be scaled in 24-watt steps by varying the number of standard generator slices, usually without other design changes. Any intermediate power level can be provided by minor modification of the radiator fin dimensions. In the earlier multihundred-watt isotope generator, changing the power level required major redesign and requalification of the heat source; even in the GPHS generator, which uses the same modular heat source as the MITG, changing the power level would usually require major changes in the thermoelectric couples and circuit.

The MITG also promises a substantially higher specific power than provided by present RTGs, without any reduction in safety and with increased reliability. It permits performance checking of individual thermoelectric modules in the assembled converter and replacement of any deficient ones. The MITG should be more economical because of the modularity, scalability, and greater flexibility in matching the payload's voltage requirements.

Space Reactor Technology

Space nuclear-reactor power systems are another power source for generating electricity for spacecraft. Like RTGs, reactor powerplants are basically heat engines; they convert the heat from the fissioning of uranium-235 into electricity through either static (e.g., thermoelectric element) or dynamic (e.g., rotary shaft) subsystems. The reactor power system has growth potential because of the greater energy release available in the fission process (almost 200 million electron volts per fission of uranium-235 versus about 5.5 MeV per alpha emission from plutonium-238). In weight, a space reactor becomes competitive with other power sources at levels above 25 electrical kilowatts, however, the choice of nuclear power source depends on the needs of the spacecraft mission.

During 1982, the Los Alamos National Laboratory completed the conceptual design layout of a space reactor and its shield assembly, analyzed water immersion effects on reactor criticality, and tested performance of reactor-core heat pipes and the compatibility of various materials with working fluids. The swelling characteristics of the reactor fuel were also examined. Talks continued on an interagency agreement with NASA and the Department of Defense for component technology development of an SP-100 space-power nuclear reactor targeted for potential use in the 1990s.

Nuclear Waste Disposal

Conceptual studies that considered using the Space Shuttle to place nuclear waste in space as a method for permanent disposal were terminated in 1982. The studies concluded that additional costs would be expected without significant reduction in the low risk of waste disposal in mined geologic repositories.

Remote Sensing of the Earth

During 1982, the National Laboratories and other research establishments, under contract to DOE, used satellite systems for collection of earth resources imagery. In particular, remotely sensed data have been used for siting energy-generating facilities, characterizing potential nuclear-waste repository sites, developing exploration techniques for energy resources, and monitoring regional environmental trends and impacts.

Nuclear Test Detection

Several of the six pairs of Vela satellites launched for the Department of Defense from 1963 to 1970 to monitor nuclear tests under the 1963 Limited Test Ban Treaty, although degraded, were still functioning in 1982. The Atomic Energy Commission, a predecessor of DOE, developed the nuclear detection instrumentation for the Velas. Other multimission DoD satellites now incorporate the mission of surveillance for violations of the treaty ban on nuclear testing underwater, in the atmosphere, and in outer space. DOE retains the responsibility for design, fabrication, test, calibration, and some launch and operational support. DoD manages spacecraft procurement, sensor integration, launch schedules and costs, and satellite operations.

DOE conducts a substantial research and development program to support new test-detection requirements and to improve capabilities. It also conducts research toward understanding the space environment in which surveillance satellites must operate. Theoretical modeling, development, and flight testing of environmental and prototype instrumentation on NASA and DoD space systems lead to surveillance systems with substantially greater coverage, sensitivity, and discrimination.

Department of the Interior

Caretaker for more than 2 million square kilometers of public lands, the U.S. Department of Interior is responsible for managing, conserving, and developing the natural resources on these nationally owned lands. The department frequently relies on data acquired by airborne sensors for inventorying, managing, and monitoring vast, often inaccessable areas. It also experimentally uses data from sensors carried on satellites, particularly the Landsat series, for mineral and energy resource exploration and for monitoring the environment. Research in digital data analysis and the development both of new applications of Landsat and other remotely sensed data and of related technologies have aided effective management.

Bureaus and agencies of the Department of the Interior participating in remote-sensing studies during 1982 included the U.S. Fish and Wildlife Service; Bureau of Land Management; Bureau of Reclamation; Office of Surface Mining Reclamation and Enforcement; National Park Service; Bureau of Indian Affairs; Bureau of Mines; and U.S. Geological Survey's Water Resources Division, Geologic Division, and National Mapping Division.

Earth Resources Observation Systems Office

The mission of the U.S. Geological Survey's EROS Office is to develop and demonstrate applications of remotely sensed data that result from merging and manipulating digital data sets for earth science. This work supports the department's natural resource inventory, monitoring, management, and mapping responsibilities. The remotely sensed data may be acquired by spacecraft or aircraft. EROS also develops basic criteria for the remote sensing of features of the earth and coordinates data requirements, system configurations, and product formats with other agencies. It archives, reproduces, and distributes data and imagery and provides specialized training and assistance in their use.

The EROS Data Center near Sioux Falls, South Dakota, is the primary archive and distribution center for remotely sensed data. In 1982, the center trained 350 scientists and technicians from Interior, other federal and state agencies, and foreign countries in remote sensing. Sales of remotely sensed data totaled more than $4.6 million (almost $3 million in Landsat-related sales and $1.6 million in other sales, primarily aerial photographs).

Digital-Data-Base Development and Applications

EROS made significant progress in computer-aided information handling and processing of geographic, geologic, and remotely sensed data. The center developed techniques for integrating disparate digital data sets to produce spatial data bases on natural resources for analysis, planning, and management. For example, it acquired aeromagnetic, radiometric, and geochemical data from national uranium resource evaluation (NURE) for the four 2° quadrangles making up the Uinta basin region in Utah and Colorado, as well as additional aeromagnetic data, on contract, for selected sites and an extensive gravity data set. These data and geologic data obtained from image interpretation and published geologic maps are being digitized and registered to a common geographic base. Project scientists are developing interpolation algorithms for creating continuous surface data sets from the original discrete data sets.

EROS developed a digital data base of topographic, geophysical, geochemical, geological, and Landsat data for the Nabesna area, Alaska, and analyzed it using a conceptual geologic model to locate areas of high potential for porphyry-copper mineralization. A minicomputer was effective in defining the correlations between the 21 original and 19 derived data sets in this data base. All areas indicated by the model as having high potential for copper were confirmed as being intensely altered in the field. Similar techniques are being used to test the geologic-data-base concept in the lead-zinc district near Rolla, Missouri.

The Fish and Wildlife Service's Refuges Division and EROS produced land-cover and terrain digital data bases and maps for the Kenai and Togiak National Wildlife Refuges and surrounding areas in Alaska. These data bases were developed in response to the Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96487), which was signed into law in 1980. The map products, digital files, and tabular summaries have met the information needs of planners as well as biologists concerned with refuge management. The service will use the methodology demonstrated in this project for the remaining 14 national wildlife refuges in Alaska.

To study the availability of water for energy development near the Black Hills of South Dakota and Wyoming, EROS is developing a hydrologic information system—a multiple, digital data base for the exploration, inventory, evaluation, description, and prediction of water resources. Better information on resources is needed because of the increasing use of water and the complexity of water problems. The data base will contain many kinds of geoscience data, including topographic, hydrologic, geologic, geophysical, geochemical, and remotely sensed image data. It will be used to model streamflows, water infiltration, and ground-water movement in the study area.

EROS and the Bureau of Indian Affairs concluded a demonstration project to evaluate the usefulness of Landsat digital data, aerial photographs, and ancillary data for mapping irrigation potential on 500 000 acres of tribal and individual trust lands in South Dakota. The use of remotely sensed data and manipulation of ancillary data within a geobased information system met management needs in a timely and cost-effective manner.

Data Handling

Designed and put into effect at the EROS Data Center, a system for registering Landsat data to a map base as well as for automatically registering temporal images to each other supported EROS cooperative projects and other department users. As additional improved techniques for analyzing Landsat data emerge, larger areas are incorporated into projects. Taking further advantage of the synoptic coverage characteristics of Landsat, multiscene digital mosaics can cover these larger areas.

A new software function on the EROS Data Center computer system converts computer classifications in raster format to polygonal formats, permitting ground-cover classes to be plotted as polygons and cartographic detail to be generalized. This technique provides an important bridge from image processing of raster data to spatial analysis techniques employing vector (line) representations. A second function converts digital line-graph data from vector to raster format for use in image analysis systems. Computer hardware and software improvements in the EROS digital image-processing system increased data-handling capabilities for *Landsat 4* multispectral-scanner image data and prepared for a new earth-coverage pattern and spectral-band-numbering system associated with the launch of *Landsat 4* on 16 July 1982.

Remote Information Processing

EROS completed the specifications of a remote information-processing station (RIPS) to extend the use of Landsat data and other remotely sensed data to field users. RIPS uses small, inexpensive computers in field offices to enhance images and other spatial data for analysis, either independently or through communications with a large "host" computer. A prototype teleconferencing system was set up to permit RIPS users to exchange ideas, problems, and capabilities without being limited by local office hours.

Monitoring the Environment

Department of the Interior bureaus and other federal agencies use aircraft and satellite sensor data to monitor all aspects of the environment, from the atmosphere to the earth's surface.

Land-Cover Inventories

The Bureau of Reclamation analyzed Landsat images to inventory land-cover types for the 59 500 square-kilometer area of the Solomon and Republican River basins of Kansas, Nebraska, and eastern Colorado and the 17 221-sq-km Tularosa basin in New Mexico. Information derived on land and water use in the Solomon and Republican basins helped determine effects on current and future water supply. For the Tularosa basin, the bureau is studying the relationship between land cover and near-surface ground water to promote the most economical use of the water and to prevent salinity buildup at the surface.

In cooperation with the U.S. Forest Service, EROS evaluated the utility of high-altitude photographs, Landsat images, and Landsat digital data in providing information on vegetation cover in urbanized areas for a test site in Syracuse, New York. The project examined (1) the consistency of stratifying areas according to a prescribed set of guidelines based on vegetation occurrence and (2) the accuracy and precision of discriminating specific vegetation features within prescribed areas. Results showed a great inconsistency in stratifying areas on all data formats, but indicated that acceptable accuracy and precision for discriminating specific vegetation features is best realized on high-altitude photographs. The Forest Service requested that the project be continued, using *Landsat 4* thematic-mapper data when they become available.

In anticipation of the new generation of instruments on *Landsat 4* (and its ground spare, Landsat D'), the National Park Service in 1981 and 1982 began three experimental projects—in the Great Smoky Mountains, Big Bend, and Yosemite National Parks—to determine whether the new higher resolution and different spectral bands will permit more accurate resource classifications. The projects are now computer-processing data gathered by NASA and Environmental Protection Agency aircraft to simulate *Landsat 4* data. Preliminary results from Big Bend had successfully separated 25 different vegetation land-cover classes, a far greater number than was possible for similar environments with previous Landsat technology.

Forest Fuels Mapping and Fire Control

The Bureau of Land Management (BLM) and EROS continue to investigate the use of satellite data from the National Oceanic and Atmospheric Administration's advanced, very-high-resolution radiometer (AVHRR) to plan wildfire suppression and prevention. While the AVHRR ground resolution is only about 1.1 km (contrasting with Landsat resolution of 79 m), it provides spectral coverage of the same area every day, and digital products are available for analysis on the same day. Preliminary results show that the AVHRR can effectively provide near-real-time synoptic data for time-series monitoring. Data can be interpreted to define the relative amounts of standing green biomass (location of greatest fire potential) and to monitor the seasonal growth of annual grasses and advent of their curing (time of greatest fire potential).

Water Resources Analysis

Knowledge of the characteristics of drainage basins (their area, slope, land cover, and other features) improves prediction of streamflow. Digitial Landsat and topographic data are used to originate mapping methods for evaluating changes in basin development. Thematic-mapper images from *Landsat 4* should enhance this capability.

Hydrologic data are routinely transmitted by radio from more than 480 U.S. Geological Survey water-gauging stations to a NOAA Geostationary Operational Environmental Satellite (GOES) for relay to ground-receiving stations linked to a USGS computer network. The data are available within minutes to water management agencies throughout the United States for operational planning and early warning of extreme events, such as floods. Most of the platforms relay only hydrologic data, although certain geologic information—such as seismic, strain, and magnetic data—are also available. For example, 20 platforms in the vicinity of Mount Saint Helens, Washington, transmit hydrologic and geologic data.

The Bureau of Reclamation inventoried the playa basins of the 246 000-sq-km area of the Texas high plains, analyzing Landsat computer-compatible tapes from nine scenes acquired in the wet season and five in the dry season. A total of 4153 playa lakes larger than 7500 sq m were found in 58 counties from five states in the study area. The bureau also developed multidate models of water quality from Landsat images of the North Platte Reservoir in Wyoming and tested the models, with favorable results, on Landsat images of Flaming Gorge Reservoir. Very good relationships were developed for mapping water clarity, chlorophyll concentrations, and phosphorous concentration.

The USGS Water Resources Division is using side-looking radar images acquired from the *Seasat* satellite in 1978 and from aircraft to map fracture zones in a clay formation in New Jersey. Knowledge of the location and extent of the fracture zones permits siting waste disposal away from areas where liquid waste may seep downward and contaminate ground-water supplies.

Irrigation Analysis

The Bureau of Reclamation entered into a cooperative agreement with the state of Wyoming to monitor the consumption of water by irrigation on the 39 000-sq-km drainage basin of the Upper Green River. Using Landsat data, simulated thematic-mapper data, and aerial photographs, this project will not only provide the needed information for the Wyoming Water Development Commission but will also lead to methodology for future use in other parts of the Colorado River basin.

Weather Monitoring

The Bureau of Reclamation uses GOES images on all Project Skywater field projects to collect cloud data in near real time. It uses GOES digital data to observe wintertime extratropical storm systems for the Sierra Cooperative Pilot Project (SCPP) in California and the Colorado River Enhanced Snowpack Test (CREST) in a five-state region of the Rocky Mountains. Observations in the SCPP are to determine to what extent the cloudtop temperatures of both convective bands and overcast decks can be monitored from geosynchronous altitudes. For CREST, objective analyses of cloudtop temperatures and mesoscale features are to produce a climatology of wintertime storm conditions in six subbasins in the Colorado River basin. These analyses will improve our understanding of winter orographic storm systems and provide information for designing CREST. A total of 150 solar-powered portable meteorological monitoring (PROBE) stations support SCPP, CREST, the Wind Energy Program, and other Bureau of Reclamation activities.

Mine Development and Safety Monitoring

BLM completed a two-year project to develop techniques for using Landsat data to monitor BLM land for unauthorized exploitation of minerals. Automated comparison of the energy reflected from the same land on different occasions (as expressed in digital brightness values in the data), has been an accurate, fast, and cost-effective means of identifying locations where increased reflected energy indicated a possible change in land cover. Increased reflectance, frequently coinciding with the removal of vegetative cover, justifies further field investigation. This method permits BLM to monitor effectively millions of acres annually and to preplan the deployment of personnel into only the localized areas where the possibility of mineral trespass is indicated. Beginning in fiscal 1983, the technology developed will be applied operationally to bureau lands.

The Office of Surface Mining uses large-scale aerial photographs of active surface-coal-mine areas in the southern Appalachian basin to detect, inventory, and monitor active mining areas and to decide priorities for spot checks for upcoming complete inspections of representative mine sites. Coverage of alluvial valley floors in the western U.S. coal states verifies the mine plan-review process. The office also uses thermal-infrared-scanner images to find the extent of the surface expression of underground mine fires and waste bank fires in the northern Appalachian anthracite coal fields of Pennsylvania and subsurface mine fires in northern Wyoming's Powder River basin.

The Bureau of Mines concluded a two-year contract with Science Systems and Applications Inc., of Seabrook, Maryland, to test the usefulness of Landsat images for remotely inventorying mine-waste stockpile areas. Four mine sites were selected to investigate response of the systems under varied conditions of climate, topography, and vegetation. The test results were verified by low-altitide aerial photographs, topographic maps, and ground data. The contractor concluded that surface mine-waste areas are extremely difficult to classify by automated digital-image processing techniques. Of four methods used in the study, none provided consistent results for the sites studied. Manual interpretation of Landsat images coupled with aerial photographs may provide an alternative method of locating and studying waste dump changes at specific mine sites.

Geology

Discrimination of Alteration

Geologic Division, USGS, used spectral reflectance to discriminate gossans (decomposed rock or vein material of reddish color resulting from oxidized pyrites) from pseudogossans in the Mount Isa-Hilton and Lady Loretta massive sulfide deposits in Australia. "Pseudogossan" is an Australian term for a limonite concentration that is highly anomalous geochemically, but that is totally unrelated to mineralized rock. Historically, the only way to differentiate a pseudogossan from a true gossan has been by drilling. In cooperation with Commonwealth Scientific and Industrial Research Organization (CSIRO) and Mount Isa Mines, samples of gossans and pseudogossans were collected from the Mount Isa-Hilton deposits, Lady Loretta deposit, and surrounding barren areas in Queensland. Laboratory studies of spectral properties in the 0.4- to 1-micrometer region by CSIRO and in the 0.8- to 2.5-micrometer region by USGS have classified these samples into three distinct groups. Each of the three sample groups has a combination of spectral properties distinct from the others; gossans lack kaolinite, but pseudogossans and all other samples contain kaolinite. The gossans and pseudogossans are well-exposed and have spectral differences sufficient to permit mapping of gossans from remotely sensed multispectral data.

Lithologic Discrimination

EROS made significant progress in 1982 on studies using thematic-mapper simulator data from the Uinta basin region of Utah and Colorado to investigate and document improvements in lithologic discrimination of sedimentary rocks. Data from five study areas of varying geologic and topographic condition were geographically registered and digitally enhanced. Interpretations of the enhanced images show variable, but always significant, improvement in the lithologic separation relative to that possible with Landsat multispectral-scanner data.

Cartography

Landsat 4

The National Mapping Division continued investigating applications of Landsat data and defined experiments to be undertaken with *Landsat 4* images, using the geometric, radiometric, and resolution characteristics of data from the thematic mapper and multispectral scanner.

New editions of the Worldwide Reference System (WRS) index maps were designed to show cloud cover data for *Landsat 1, 2,* and *3* coverage. Planned centers of *Landsat 4* scenes will be included on the reverse side of the map. Complete world coverage is provided in 26 index sheets now in production. A new Landsat ground-station map indicates areas where Landsat coverage can be received directly. Because *Landsat 4* orbits at a lower altitude than *Landsat 2* and *3*, its area of direct reception is significantly smaller at each ground station.

The National Mapping Division continued to use Landsat data in the production of image maps and to respond to requests for assistance from foreign governments. The following projects are being pursued or have recently been completed: in Antarctica, mapping the Ronne Ice Shelf, Berkner Island, and Filchner Ice Shelf quadrangles at 1:1 000 000 scale; in Cape Cod, the New Bedford quadrangle at 1:250 000 scale; in the Arabian Peninsula, the Precambrian Shield area at

1:250 000 scale, Kingdom of Saudi Arabia at 1:500 000 scale, and overall Arabian Pensinsula at 1:2 000 000 scale.

Mapsat

A patent for an automated mapping satellite (*Mapsat*) was issued to the Department of Interior on 2 February 1982. The patent describes an efficient, cost-effective, automated concept for mapping the earth from space. The department also successfully filed a continuation of this patent, entitled "Automated Close-Range Stereo Mapping System," with the Patent Office and began investigating the factors that affect automated correlation in order to define parameters better for an operational earth-sensing stereoscopic satellite system. So far, DOI has developed a computer program to reconstruct mathematical terrain models based on reflectance and digital elevation models based on Mount Saint Helens for correlation studies.

International Activities

Workshops

U.S. Geological Survey scientists held two, month-long, remote-sensing workshops during 1982 for 44 scientists from 16 countries at the EROS Data Center. Three advanced remote-sensing courses were held at the Geological Survey's Center for Astrogeologic Studies in Flagstaff, Arizona, for 14 scientists from 14 countries. Geological Survey scientists participated in remote-sensing courses at the University of Ife, Ile-Ife, Nigeria, and at the Alberta Remote Sensing Center in Edmonton, Alberta, Canada.

International Cooperation in Fuels Exploration

The first scheduled exchange visit of project 2A, Applications of Remote Sensing Techniques to Petroleum Exploration, took place in September and October 1982, when five Chinese scientists from the Scientific Research Institute for Petroleum Exploration and Development, Ministry of Petroleum Industry, the People's Republic of China, visited the EROS Data Center for joint studies with EROS scientists. The productive exchange visit concluded with detailed discussions of concepts and procedures for developing and implementing digital data bases for geologic applications and with definitions of work to be carried out by each side before the return visit to China by EROS scientists, scheduled for summer 1983. A summary paper, "Evaluation of Image Processing of Landsat Data for Geologic Interpretations of Qaidam Basin, China," was presented at the International Symposium on Remote Sensing of Environment, Second Thematic Conference, Remote Sensing for Exploration Geology, in December 1982.

Department of Agriculture

Significant achievements of the U.S. Department of Agriculture (USDA) in the fields of aeronautics and space during 1982 focused on research in aerospace remote sensing as a data source in agriculture and renewable resources and on research for developing lifting platforms based on lighter-than-air technology.

Agriculture and Resources Inventories

AgRISTARS (Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing)—a joint research program of USDA, National Aeronautics and Space Administration, Department of Commerce, and Department of the Interior—was revised during 1982 to reflect current budget constraints, USDA priority information requirements, and research progress to date. AgRISTARS is a multiyear program of research, development, evaluation, and application of aerospace remote sensing to support national management of agricultural and renewable resources. The revised program focuses research on USDA priority needs, facilitates use of research results, and simplifies the program's organizational structure.

The department will continue AgRISTARS, which began in fiscal 1980, through fiscal 1986. The complexity of the research dictates a fairly long, stable effort to exploit satellite sensors fully, including the thematic mapper (TM) and other experimental sensors. Despite reduction in its scope, AgRISTARS is still a large program that will yield important results. With user requirements increasing, the need to develop remote-sensing technology is even more acute now than it was when AgRISTARS was originally planned. Program objectives continue to focus on primary USDA concerns in developing and using aerospace remote-sensing technology as a cost-effective, timely, and reliable source of information. Although the research program was originally planned to end in fiscal 1985, components will be extended through fiscal 1986 to use and assess data from the *Landsat 4* satellite, especially from its thematic mapper.

Organizational Changes

Overall research policy and direction will be provided by an Interagency Coordinating Committee (ICC), the result of reducing three levels of management and coordination to one. A Program Management Group within the ICC will be responsible for the day-to-day management of the program. Ad hoc Application Research Teams will link users more closely with research and will help users incorporate results into operational activities.

Significant Achievements

Technical achievements in the AgRISTARS program in calendar 1982 included:

- Use of Landsat data for domestic crop estimation in five states.
- Development of models to provide warnings of potentially damaging conditions; for example, water and temperature stress. Substantial progress was made in the variety of crops and conditions that can be treated and in the facility with which such models can be tested, using a new data base for the Great Plains.
- Successful testing of an automated technique for classifying corn and soybeans near harvest over large areas of the Corn Belt.
- Testing of techniques to estimate the area of spring small grains early in the season. Three techniques show promise of being as accurate as previous end-of-season results.
- Analysis of simulated thematic-mapper data over various types of forests, with results indicating a high level of accuracy in delineating major forest types.
- Initial analysis of data from the new thematic-mapper sensor on *Landsat 4*, verifying that greatly improved agricultural information is contained in the data. Methods to extract the information show promise.

Aerial Crane for Logging

Continuing concern for protecting the environment and maintaining the reproductive capability of forested areas has provided impetus to the Forest Service of the Department of Agriculture to develop new methods for aerial logging. Balloons, helicopters, and cable systems are among technologies being considered.

In recent years, helicopters have provided a way to harvest timber on steep terrain and on fragile soils, substantially increasing the available timber supply. The helicopter, however, has a limited range for economic transportation of logs, about one and half kilometers at present. Because in many forested areas, particularly in the Northwest, it is not economically or environmentally possible to construct roads that close to a tract of timber, a capability to extract logs by air over greater distances would provide a valuable alternative in meeting management objectives.

In 1976, the Piasecki Aircraft Corporation submitted a proposal to the Forest Service to build and test a "Heli-Stat" as a possible aerial logging system. In simplest terms, the Heli-Stat (helicopter plus aerostat) consists of a blimp attached to four helicopters by an understructure of aluminum tubing. The helicopter-balloon idea is not new; it was first patented by Piasecki in 1961. The blimp or aerostat supports the weight of the understructure—the helicopters—which in turn are free to provide the lift for heavy objects. A control system connecting the four helicopters permits operation from one point. The Heli-Stat has a projected payload of approximately 24 metric tons, more than twice that of the largest helicopter now used for logging. Piasecki Aircraft studies indicate that the Heli-Stat can transport logs 1.5 to 10 km at a cost comparable to that of conventional helicopter logging. The Heli-Stat itself will lift the logs.

A U.S. Navy evaluation of the Piasecki proposal concluded that it was technically feasible, and the Navy offered to act as contracting and program management agent for the Forest Service during the machine fabrication phase. The Forest Service signed an agreement with Naval Air Systems Command to permit the Navy to act as technical representative and contract administrator because of its greater experience with lighter-than-air systems. The Navy also proposed to make available the helicopters and aerostat, a fly-by-wire system, associated parts and equipment, and hangar space for fabrication in Lakehurst, New Jersey. In addition, the USDA and Department of Transportation agreed to a mutual interest in the program.

Funding for the Heli-Stat was about $2 million in fiscal 1980, divided among the Forest Service, the Coast Guard, and the Department of Transportation. In fiscal 1981 and 1982, the Forest Service assumed responsibility for all activities and appropriations. The fabrication contract has added $10 million, with an additional $15 million to be spent on logging tests. Fabrication of the Heli-Stat is being completed and, after test phase in New Jersey and the Allegheny National Forest in Pennsylvania, the craft will go to the Pacific Northwest for experiments in hauling old-growth timber. The Heli-Stat will be tested on five sites in the Pacific Northwest and Alaska.

Federal Communications Commission

Demand for both international and domestic satellite communication services continued to expand in 1982. The International Telecommunications Satellite Organization (INTELSAT) upgraded its 12-satellite global service by launches of its fourth and fifth Intelsat V satellites and introduction of high-capacity digital transmission. The United States is being served by domestic commercial satellites from 15 locations, 12 operating in the 4-6 gigahertz (GHz) bands and 3 in the 12-14 GHz bands. The International Maritime Satellite Organization (INMARSAT) began commercial maritime service. FCC issued construction permits to begin building direct-broadcasting satellites (DBS) for direct-to-home television service.

Communications Satellites

INTELSAT

Operating satellites in the INTELSAT global communications system at the end of 1982 included one Intelsat IV-A and two Intelsat Vs in the Atlantic Ocean region, two Intelsat Vs in the Indian Ocean region, and one Intelsat IV-A in the Pacific region. Six in-orbit contingency and leased domestic-service satellites were also in service. *Intelsat V F-4* and *F-5* were launched during 1982; *F-6* was to be launched early in 1983.

INTELSAT plans launches of up to four more Vs in 1983, followed by six improved V-As in 1984 and 1985, to meet expanding international demands and provide regional and domestic services to member nations. Four Intelsat Vs, to be capable of providing maritime services, are expected to be leased by INMARSAT. INTELSAT in 1981 approved introduction of time-division multiple access (TDMA), a transmission technique that will markedly increase satellite communications capacity. It awarded a contract in early 1982 to Hughes Aircraft Corporation for the new Intelsat VI satellites, to become operational in 1986.

Maritime

The INMARSAT system on 1 February 1982 replaced the commercial maritime-mobile satellite services previously provided by the U.S. Marisat system. Communications Satellite Corporation (Comsat) is the United States signatory in INMARSAT. At the end of 1982, INMARSAT was serving 1309 ship and 38 land stations around the world. U.S. entities owned 292 ship and 17 land stations. On 19 February, by Notice of Proposed Rulemaking, the commission requested public comments on proposed amendments of its rules to conform with the INMARSAT equipment and operational requirements. The rules are expected to be amended in 1983. National and international efforts continued toward establishing technical and operational characteristics of a satellite communications system for a future global maritime distress and safety system. Selective calling will alert only those units in any ocean area that can aid the ship in distress. An international agreement is expected by about 1990.

Domestic Commercial Communications Satellites

The domestic commercial communications satellite network capacity increased during 1982 with the launch of four satellites in the 4-6 GHz bands and one in the 12-14 GHz bands. *Westar 4* and *5* (Western Union Telegraph Company) replaced *Westar 1* and *2*, which were launched in 1974 and are nearing the end of their useful lives. *Westar 1* and *2* are now colocated and will function as a single satellite until they expire. *RCA-Satcom 4* and *5* (RCA American Communications) have expanded the capacity of the Satcom network. *RCA-Satcom 5* is dedicated primarily for services to and within the state of Alaska. In the 12-14 GHz bands, *SBS 3* (Satellite Business Systems) is the third operational satellite in the SBS communications network.

The number of available orbital positions with the present 4° satellite spacing in the 4-6 GHz bands is nearing exhaustion. To accommodate future satellites and to expand the capacity of the domestic satellite communications network, FCC studied methods of placing satellites as close as 2° apart in both the 4-6 and the 12-14 GHz bands. As a result of satellite industry comments on proposed methods and further FCC studies, the commission will release a reduced-orbital-spacing plan at the beginning of 1983 for domestic satellites to be launched through the mid-to-late 1980s.

Introduction this past year of new technology for more efficient use of satellites and the frequency spectrum brought economic benefits and improved services to satellite users. Common carriers are incorporating companded FDM-FM (frequency division multiplexed -frequency modulated) voice channels that double or triple transponder use. Companded single sideband (CSSB), employing amplitude modulation (AM) in place of frequency modulation makes a transponder three to six times more efficient. (A compandor is a device that, by the use of matched channels, compresses the voice channel before it enters the transmission link and expands the received transmission before it reenters the voice channel.)

The commission authorized developmental use of transportable ground stations with 4.5-meter antennas for emergency and other short-term needs. These stations can provide up to 24 voice channels and 1 video channel and can be placed in operation within a few hours of the service request. Transponder sales are now permitted on a limited number of satellites. These noncommon carrier transactions, which supplement conventional transponder leases under tariff, satisfy particular needs for telecommunication services. The sales help prospective entrants to secure the large amounts of capital necessary to construct satellite facilities, provide a way of sharing the risks unique to satellite technology, and help ensure an adequate supply of transponders in the future.

FCC, representing the United States in negotiations with Canada and Mexico, concluded an agreement for accommodating their domestic satellites without significantly disturbing the current location of U.S. and Canadian satellites. Agreements were also reached on use of domestic satellites for transborder services to and from Canada and to certain Caribbean points.

Direct-Broadcast Satellite (DBS)

Direct-broadcast satellites in geostationary orbit will beam programs directly into individual homes without the intermediary of local television stations or cable systems. Service areas in the United States will receive multiple channels from a single satellite, and several satellites will be capable of serving a given service area. The downlink frequency will be in the 12.2–12.7 GHz band.

Final rules for interim DBS systems were adopted 23 June 1982. The rules impose only the minimum requirements necessary to ensure that DBS systems operate in conformity with the Communications Act and international agreements. The commission accepted nine applications requesting authority to provide DBS service to the 50 United States, Puerto Rico, and the Virgin Islands. Construction permits to build satellites in the DBS frequency band have been issued.

In addition to studies tailored to indigenous DBS systems, the United States is preparing for the Regional Administrative Radio Conference (RARC-83), to be held in Geneva in the summer of 1983 to plan for ITU region 2 administrations. The United States plans to promote a more flexible approach than a priori planning (used at the World Administrative Radio Conference of 1977), in which administrations are assigned channels. FCC proposes assigning a block of frequencies to service areas, within which each administration can partition the band as its needs require. The United States has promulgated three notices of inquiry, set up an RARC-83 Advisory Group, and attended an ITU Conference Preparatory Meeting in Geneva June–July 1982. A government ad hoc group will prepare the U.S. position for RARC-83.

Experiments and Studies

FCC continued to prepare for the first session (July 1985) of the World Administrative Radio Conference (Space WARC). The second session will be held in 1987. The conference will seek to guarantee for all countries equitable access to the geostationary satellite orbit and the frequency bands allocated to space services. FCC released a second notice of inquiry in June 1982, requesting public comment on preparations. The FCC Advisory Committee for the Space WARC, bringing the nongovernment sector into the preparations, met in January, March, and October 1982. The committee is developing preliminary reports on its charter of work. A final report is due December 1983.

Emergency communications experiments continued using Applications Technology Satellites *ATS 1* and *ATS 3* (launched in 1966 and 1967). Narrow-band VHF transponders on these satellites permit experimenters to send voice and data communications to and from fixed and portable stations. Messages deal with medical emergencies, state government operations, search and rescue, and church administration.

Use of the Geostationary Operational Environmental Satellite *GOES 3* (launched in 1978) to collect environmental data continued to increase. The satellite is operated by the National Earth Satellite Service of the National Oceanic and Atmospheric Administration (NOAA). Observations and measurements of physical, chemical, or biological properties of oceans, rivers, lakes, solid earth, and atmosphere are gathered by data-collection platforms, relayed to the satellite, and then distributed to users for fire-weather forecasting, prediction of water runoff, and information on the environment near offshore oil-drilling platforms.

Department of Transportation

The basic responsibilities of the Federal Aviation Administration (FAA), as defined in the Federal Aviation Act of 1958, are to promote aviation safety, ensure the safe and efficient use of the national airspace, foster civil aeronautics at home and abroad, develop and operate a common system of air navigation and traffic control for both military and civil aviation, promote aviation security, develop an effective national airport system, and ensure that civil aviation poses as little risk to the environment as possible. Extensive research, development, and engineering programs, both inhouse and under contract, engage FAA headquarters in Washington, the FAA Technical Center in Atlantic City, the FAA Civil Aeromedical Institute in Oklahoma City, and on occasion the DOT Transportation Systems Center in Cambridge. In matters of common interest, the agency also carries on research jointly with NASA, DoD, other agencies of the executive branch, and the research echelons of friendly foreign governments. Research and development focuses on three principal categories: aviation safety, environmental research, and air navigation and traffic control.

Aviation Safety

Fire Safety Research

For the past several years, FAA, NASA, and the British Royal Aircraft Establishment (RAE) have been developing FM-9, an antimisting, kerosene fuel additive of British origin. Jet fuel with FM-9 is expected to be highly effective in reducing postcrash jet-transport fires from ruptured fuel tanks. At present, the released mist of vaporized fuel often ignites to form a fireball capable of consuming everything in its path. As 1982 closed, FAA and NASA were readying FAA's obsolete B-720 for a full-scale crash test to determine the effectiveness of the antimisting FM-9 in inhibiting fireball formation. The crash will also permit crashworthiness tests of seats, cabin furnishings, and galleys.

Aviation Security Research

FAA continued efforts to detect explosives in air cargo, checked baggage, and baggage carried by individuals. Of the six methods under study in the past several years, two—one based on the use of gerbils and rats, the other on the detection of explosive vapors—were discarded as unlikely to meet requirements; a third, a walk-by detector based on explosive vapor sampling, was sent back to industry for improvement toward possible future use. The remaining three methods had demonstrated a potential to do the job with further development.

X-ray Absorption. The absorption device, in prototype form in 1982 and considered particularly suitable for detecting explosives in checked baggage, is based on an automatic, computerized analysis of the size, shape, and x-ray density of the baggage checked. Two prototype detectors have been preliminarily tested—one at Dulles International Airport, the other at the FAA Technical Center. The detector at Dulles did moderately well in its preliminary operational test. However, the many false responses made clear that the device would have to be improved to be fully effective. The Technical Center found the trouble was in the detector's software and, at the end of the year, was testing a modified software program from the contractor.

Thermal Neutron Activation. A device that detects explosives by reference to thermal nuclear reactions has proved itself particularly useful for screening air cargo. Portable prototypes were tested at the international airports at Pittsburgh and Boston, and FAA decided to modify the system for use by airline personnel in emergency and threat situations.

Nuclear Magnetic Resonance. Tests at the regional airport at Dallas-Fort Worth showed that a laboratory scale model of a device that relies on the characteristic response of explosive molecules subjected to magnetic and pulsed radio fields could detect explosives. In 1982, the laboratory model was converted into an operational system and readied for operational testing.

Aeromedical Research

Two developments in aeromedical research were noteworthy during 1982. The first was in personnel testing—specifically, the results of a new test battery devised by FAA for selecting air-traffic-control trainees. The second was in improving pilot judgment and behavior under stress, to the extent that this could be done by didactic methods.

Screening Air-Traffic-Controller Applicants. FAA used a new customized job-related test battery for the first time in late 1981 to screen 125 000 applicants for positions as air traffic controllers following the strike by the Professional Air Traffic Controllers Organization and the subsequent dismissal of 11 400 striking controllers. The first classes entering the FAA Academy after the strike included persons screened by the old test battery and selected from the old register as well as persons tested by the new battery and selected from the new register. The difference in the pass-fail performance between the two groups was significant. The 479 persons from the old register had a pass rate of 43 percent; the 965 from the new register, a pass rate of 71 percent. With 6000 persons scheduled to move through controller training in the next two years, such improved rates were welcome. The primary return from improved pass rates is the projected saving in time required to rebuild the work force. The FAA Academy also expects to save about $10 000 per student, or an aggregate of $50 million during the rebuilding program.

Improving Pilot Judgment. Statistics show that half of all civil aviation fatalities are related to poor pilot judgment. The FAA Office of Aviation Medicine and the FAA Technical Center concluded a contract with Embry-Riddle Aeronautical University to develop materials to improve the pilot's judgment particularly under stress, by increasing his ability to make decisions and assess risks and by changing his attitude toward engaging in potentially dangerous activities.

Embry-Riddle developed prototype training manuals for both student pilots and flight instructors and tested their effectiveness on resident student pilots. Those who had used the manuals and taken the training exhibited better inflight judgment than others at the university who had not received the training. During cross-country flights in which student pilots were subjected to a series of inflight decision-making situations controlled and monitored by an instructor, those who had taken the training made correct decisions 74 percent of the time, contrasting with 58 percent for pilots who had not taken it.

Meanwhile, in August 1982, the Canadian government in cooperation with FAA completed an independent evaluation of the Embry-Riddle prototype manuals. In observation flights with pilots who had already received their Canadian private pilot certificates, those who received judgment training made correct decisions in 83 percent of the situations; the others made correct decisions in only 43 percent of them.

Airport Pavement Research

In 1982, as in previous years, the greater part of FAA funds allotted to U.S. airports under the Airport Development Aid Program (ADAP) has gone for airport pavement construction. Research has sought to ensure the most effective use of this money and to maintain the highest safety standards.

Among research projects was study of the use in pavement construction of nonwoven fabric made of synthetic fibers. Polymerized, feltlike substances such as polypropylene, a thermoplastic resin that can be used safely and effectively as a sandwich between layers of bituminous pavement, may materially reduce the thickness of the pavement and provide the same strength and performance as before but at lower cost. The nonwoven fabrics, now available in rolls from manufacturers, have so far been successfully used in the construction of drains, subdrains, and pavement foundations. During 1982 the fabrics were tested as a means of correcting and halting reflection cracking of bituminous pavements over existing cracked surfaces.

Research to establish new criteria for rigid and flexible overlay pavements is being conducted jointly with the Defense Department at the Waterways Experiment Station of the Corps of Engineers in Vicksburg, Mississippi. It provides criteria for the structural design of Portland cement, concrete, and bituminous overlays of existing pavements. Present criteria were derived from military requirements and were based on failure modes not necessarily applicable to civilian traffic today. The Corps of Engineers is making tests to determine optimum pavement thicknesses for civil airport operations.

Environmental Research

In 1982, FAA continued research in support of its regulatory mission to control aircraft noise and sonic boom and to limit the adverse effects of aviation on the atmosphere. Primary activity was in helicopter noise. A secondary area of activity was aviation-affected air quality at airports and environmental impacts on the upper atmosphere.

Rotorcraft Noise Reduction. In 1981, FAA withdrew proposed noise standards for civil helicopters, as both premature and costly. In 1982, it undertook with NASA and the helicopter industry a joint national rotorcraft program to develop a cost-effective noise-reduction technology as a basis for a new proposed standard.

Air Quality. FAA terminated its High-Altitude Pollution Program (HAPP) in 1982. The program had examined over several years the potential effects of high-altitude aircraft engine emissions on the earth's atmosphere, especially a potential decrease in stratospheric ozone. The study concluded that the effect of expected fleets of high-altitude aircraft on surveillance, however, in cooperation with other agencies in the United States and abroad, to determine if future research may be needed.

Air Navigation and Air Traffic Control

National Airspace System Plan

On 28 January 1982, FAA issued a National Airspace System Plan stating how the agency proposed to modernize its air traffic control and air navigation system in the next two decades. In a public hearing, the FAA administrator emphasized that the existing U.S. system for guiding aircraft—while the safest and most efficient in the world—is made up of a mix of technologies, many of them old. It is expensive to operate and maintain, allows little room for expansion, and is difficult to adapt to new situations. By the year 2000, the number of commercial aircraft is expected to jump 42 percent; the number of private planes, 94 percent; the number of air taxi and commuter aircraft 175 percent. Since the existing system cannot handle that load safely, measures to expand and improve it cannot long be delayed.

FAA estimated that modernizing the system would cost as much as $7.16 billion over the first 5 years, when the heaviest expenditures would be made, and perhaps reach $9 billion by the end of the first 10 years. Savings, on the other hand, would be significant—at least $25 billion in reduced operation and maintenance costs alone during the implementation of the plan. The savings would result from higher levels of automation, consolidation of facilities, the use of lower-cost technology in the telecommunications net that ties the system together, and a need for fewer controllers, technicians, and maintenance specialistcs to run the more efficient and better articulated system planned. These savings would be in addition to enhanced safety and efficiency.

En Route and Terminal-Control Systems. The NAS plan takes two principal approaches to revamping the en route and terminal ATC systems: (1) using compatible hardware and software elements and (2) using higher levels of automation. The IBM 9020 computer used in the ATC system today is not expected to prove adequate for the projected traffic growth beyond the mid-1980s. Moreover, the 9020 cannot accommodate the higher levels of automation being developed to reduce operational costs, enhance safety, and permit aircraft to use fuel-saving routes. The plan calls for replacing the 9020 in the mid-1980s with a new computer that can use existing software. The new high-capability, high-reliability equipment would immediately relieve any capacity restrictions resulting from rapid traffic growth in the 1980s.

At the same time, FAA would develop new software and sector suites to replace existing consoles and displays. The sector suites are to have their own microprocessors to generate information for controller displays and to serve as back-up to the central computer complex. Computers and suites will be the same for center and terminal facilities, although computer capacity will differ. In the 1990s, new computers would provide the capacity and informational frame for higher levels of automation, known as the automated, en route, air-traffic-control (AERA) concept. AERA would permit more fuel-efficient aircraft routings and assist controllers with flow planning and traffic management. When fully implemented, AERA would automatically probe aircraft routes, detect and resolve conflicts with other aircraft, and issue clearances to ensure safe, metered, fuel-efficient traffic flow.

Flight Service System Modernization. In a modernization plan already begun, FAA will consolidate its more than 300 flight service stations into 61 automated hubs. The schedule calls for the delivery by 1983 of computerized systems at 41 of the hubs, with the remaining 20 hubs to be phased in as the equipment becomes available. During 1981, all major automated hardware for the first 41 was procured and a basic model assembled. The new automated equipment will permit rapid retrieval of information for briefing general-aviation pilots on weather and flight conditions. By 1985, the first 41 sites will be in operation, using an interim model 1 system. By that time, however, FAA will begin introducing the more advanced model 2, which, in addition to the minimum weather and flight-data service available with the model 1, will display weather radar data, charts, and other essential graphics. All 61 sites are to be fully operative by 1990. Under the NAS plan, by the year 2000 the system will have an enhanced voice capability and will give pilots direct access to the computer data base via remote computer terminals as well as by touch-tone telephone. Communications switching systems interconnecting the 61 hubs will provide even greater pilot access and greater coordination between pilots and flight service specialists.

Ground-to-Air Systems. The NAS plan envisages improving both aircraft surveillance and air-ground communications with a new secondary radar system known as Mode S. Mode S, like the air-traffic-control radar-beacon system (ATCRBS) it would replace, obtains information on aircraft by querying transponders in these aircraft, reading out the coded replies, and presenting this data on radar displays. However, Mode S can also interrogate aircraft individually, rather than on an "all call" basis, and this avoids the interference that plagues ATCRBS in busy terminal areas. And, since aircraft can be addressed individually and respond in the same manner, an avenue exists for automatic air-ground data-link communications. FAA expects to provide Mode S data-link coverage to aircraft flying above 3800 meters mean sea level by 1990.

Interfacility Communications Systems. The present system for communicating between FAA air traffic control and other facilities has evolved over time. Initially, circuit costs were low, but they have escalated sharply in recent years. At the same time, competition has emerged in all telecommunications areas, providing FAA with an opportunity to take a systems approach to its interfacility communication needs and develop a national network that will provide greater routing capabilities, flexibility, growth potential, and reduced operating costs. The NAS plan calls for an integrated telecommunications network with the potential for use by other elements of the Department of Transportation. It recommends a mix of owned, leased, and satellite communication facilities and requires the system to take advantage of rapidly changing and lower-cost technologies. The plan also provides for establishment between 1981 and 1985 of a national-airspace data-interchange network (NADIN). NADIN is to evolve into a general-purpose, data transmission system with alternative routing capabilities to bypass failed or saturated areas. It will be designed to transmit by whatever medium proves most cost effective at the time the network is ready.

Microwave Landing System. The plan calls for installation of a new microwave landing system (MLS) at airports to begin in 1984, with more than 1250 in place by 1998. This equipment provides more precise guidance over a broader area than the present instrument landing system, which will be phased out during the 1990s. In 1982, FAA began a two-year final test and evaluation program using four MLSs.

Key Achievements

New Radars. Procurement of the new, long-range, air-route-surveillance radar (ARSR-3), a solid-state device with improved antenna design and built-in test equipment, continued during the year. Of the 23 ARSR-3s procured for use at operational sites, 22 were in commission by the year's end and the 23d, which had been received in Honolulu, was expected to be in operation by early 1983. Development of the new airport-surface detection-equipment radar (ASDE-3) was still incomplete, but a request for proposals for a prototype of this analog system was expected by early 1983.

DARC Enhancement. The last of 20 direct-access radar-channel (DARC) support systems went into operation at the Minneapolis air route traffic control center on 28 June 1981. The individual DARC subsystems in this version could operate the center's radar-data-processing (RDP) system when its main computer complex failed or was shut down for routine maintenance. DARC, however, could provide digitized, narrow-band alphanumeric readouts of the identity, position, and altitude only of aircraft equipped with transponders. When a controller switched to DARC, he had to lower his radar displays from the vertical to the horizontal and use plastic markers to locate aircraft not equipped with transponders. A more versatile software component has been developed to permit the controller to switch back and forth between his primary and backup systems at the touch of a button and to control both transponder-equipped and non-transponder-equipped aircraft simultaneously. New DARC software enhancement kits sufficient for all the centers were being procured at the end of 1982.

Next-Generation Weather Radar (NEXRAD). FAA's joint program with DoD and the National Weather Service to develop a new doppler, common-use, weather radar network to meet the nations's needs for the 1990s and beyond advanced to another stage during 1982. The joint NEXRAD Special Program Office awarded multiple contracts in early 1982 for a validated design concept and functional specifications. A number of government laboratories conducted research and studied the latest algorithmic developments for possible application to NEXRAD. Contract design and validation will begin in 1983, and the winning company will be selected in 1985 to produce the radar.

Automated Weather Observing System (AWOS). FAA, in cooperation with the National Weather Service and DoD, worked toward a new weather observing system that includes sensors for wind speed and direction, altimeter, temperature, dewpoint, ceiling, and visibility, and will improve safety and controller productivity. It will provide weather observations for airports qualifying under an airway planning standard issued in December 1982 and information for the weather data network for general dissemination. Weather data will also be broadcast to aircraft and provided to flight service stations, Center Weather Service Unit meterologists, and towers for controller use and for automated-terminal information-system broadcasts. Evaluation of the sensors was completed in 1982, and contracts for the first systems have been awarded. An AWOS demonstration test of 15 systems is planned, to begin in April 1983. The test will demonstrate system features in a variety of climates; afford controllers, pilots, and other users the opportunity to submit their suggestions and verify weather reports; and give FAA an indication of the maintenance and reliability of commercially available systems.

Traffic-Alert and Collision-Avoidance System (TCAS). Two versions of the new TCAS are under development: TCAS-I, a low-cost service for the general-aviation community, and TCAS-II, a more capable version for airline use. TCAS-I, although it cannot provide pilots with maneuver advisories for conflict resolution, can provide traffic alerts in cockpits of general-aviation aircraft. TCAS-II is an extension of the beacon collision-avoidance system (BCAS), adding new signal-processing techniques to ensure reliability in high-density airspace. During 1982, design guidelines for TCAS-I were completed and minimum TCAS-II standards were drafted. Also completed were engineering and operational evalutions of a minimum TCAS-II. TCAS-I implementation is expected to begin in late 1983. The TCAS-II minimum operational performance standard (MOPS) and minimum national standard (final) will be computed in 1983, with implementation expected to begin in 1984.

Environmental Protection Agency

The Environmental Protection Agency (EPA) and NASA have cooperated in research since the beginning of the Interagency Energy/Environment Program (IEEP) in 1974. IEEP provides data to federal, state, and local pollution abatement and control programs, focusing on controlling pollution from both new and existing energy production facilities. The advanced earth-surveillance systems developed by NASA are applicable to energy-related environmental research programs. However, funding for IEEP was reduced in the EPA budget for fiscal 1982. Consequently, cooperative efforts between EPA and NASA during the year were limited to the completion of three existing projects.

The first of these was the Persistent Elevated Pollutant Episodes/North East Regional Oxidant Study—the PEPE/NEROS field study. During July-August 1980, a team of researchers employed satellite systems, balloons, aircraft, and vans to document extensively the air pollution and meteorological conditions during a pollutant episode. The twofold goal was, first, to understand the origins, nature, duration, and air quality impacts of summertime stagnant air masses and, second, to understand the sources of the oxidants and oxidant precursors that affect the air quality of the northeastern United States.

Weather satellites detected the stagnant air masses, and the information gathered assisted researchers collecting field data. In addition to launching weather satellites, NASA took measurements with two advanced lidar (light detection and ranging) systems on aircraft. One system, the UV-DIAL (ultraviolet-differential absorption lidar) system, measures the atmospheric distribution of specific compounds such as sulfur dioxide and ozone. The other system, HSRL (high-spectral-resolution lidar), is an advanced lidar system that uses laser light pulses to distinguish the light scattering of air molecules from that of aerosol particles. Data from HSRL is used to investigate visibility impairment associated with atmospheric pollution. In 1982, data from both the DIAL and HSRL systems were submitted to the special PEPE/NEROS archive at St. Louis University.

The second 1982 cooperative project was a technology transfer project in which expertise gained in designing and operating NASA's UV-DIAL system was applied to developing a smaller, analogous system. NASA's large and sophisticated UV-DIAL system is mounted in an Electra aircraft where ample power is available and weight and size constraints are not severe. It is designed to function as a flexible, state-of-the-art system amenable to a broad range of applications and operating conditions. The smaller system, on the other hand, will be designed for use in small aircraft to perform routine atmospheric measurements. Development of this smaller system will be a reduction-to-practice step in the overall development of this new laser technology and may lead to some limited commercialization. During 1982, NASA reviewed for EPA a feasibility study and preliminary design for this smaller UV-DIAL system.

The third cooperative project was a continued collaboration on a small field study made during the summer of 1981. The study was designed to determine if ozone is transported from the boundary layer of the atmosphere into the free troposphere via cloud dynamics and, if so, to quantify the flux. Transfer of ozone from the boundary layer into the free troposphere has not been incorporated into existing models by any mechanism. This project tested the significance of pumping by convective clouds as a possible mechanism for transporting ground-level air into the free troposphere. Analysis of the data continued in 1982. Preliminary findings indicate that the postulated ozone transfer does occur. Efforts are continuing to quantify the flux to the extent possible with the available data.

National Science Foundation

The National Science Foundation supports research to advance knowledge in scientific and engineering fields, including astronomy and atmospheric science. Scientists contribute to this research through NSF grants and the use of NSF-supported national research centers.

Astronomy and atmospheric sciences focus on the physical and chemical characteristics of the near and far atmosphere and the distant reaches of the universe. Their boundless spatial extent is matched by a time span that ranges from investigations of galaxies 10 billion light-years away to current weather and climate phenomena and volcanic eruptions. Studies enable scientists to predict environmental changes, hazards, and opportunities with greater accuracy, and they add to our understanding of human interaction with the environment.

Astronomy

The foundation helps advance knowledge in all areas of ground-based astronomy by awards to individual astronomers, funding for new instruments, and support of five national astronomy centers. Among achievements reported in calendar 1982, astronomers using a 91-centimeter telescope at the McDonald Observatory near El Paso, Texas, found a pulsating white dwarf star that had been predicted earlier. As a result of this work and related research by others, astrophysicists can now probe the interiors of white dwarfs much as geophysicists use seismic waves to study the interior of the earth. The probes may add much to our understanding of the late stages of stellar evolution and the early history of star formation.

Astronomers also succeeded in observing the center of our Milky Way galaxy. Using a very-large-array (VLA) telescope, they discovered an exceptionally small and luminous radio source with a core that has a remarkable, spirallike pattern. The gas in that pattern seems to flow outward from a still smaller source that some think could be a black hole (a superdense space object).

An astronomer at Kitt Peak National Observatory, which NSF supports, perceived a drop of 6° centigrade in solar luminosity since the sunspot minimum of 1975-1976. This is the first time that the sun's outflow of energy has been shown to be partially controlled over the entire surface by its magnetic field; the finding confirms a 1980 theory. The Kitt Peak scientist monitored the sun's temperature with the McMath solar telescope, the largest such instrument in the world, equipped with a Fourier transform spectrometer.

Atmospheric Sciences

Atmospheric research draws on knowledge from many fields of science and mathematics. NSF supports this work through grants to academic institutions and contracts for the operation of two national centers.

Recent studies have yielded new knowledge on the possibly dangerous climatic effect of increasing carbon dioxide levels in the atmosphere. Other findings bear on drought prediction and the role of mountains in creating severe storms.

In 1982, NSF's grants for research in the atmospheric sciences produced a number of results. Among them, the Joint Airport Weather Studies (JAWS) project, a three-year experiment, conducted its field phase near Denver in the summer of 1982. The study focused on low-level wind-shear conditions during severe thunderstorms—in particular the small, intense, downward and outward gusts of air (downbursts) in a number of aircraft accidents and near-accidents during takeoffs and landings.

Basic research observations and findings from JAWS already have been used to improve local, short-term weather forecasts in the Denver area and to prepare severe-weather advisories for the National Weather Service. Scientists are finding that downbursts occur often enough to pose very real danger to aircraft. JAWS data are now available to aid development of detection and warning systems for hazardous wind shears. Wind-shear profiles will be used in flight-simulation training for airline pilots. They are also being made available to airlines and aircraft manufacturers for checking aircraft safety and performance.

In the spring of 1982, El Chichon volcano erupted in Mexico. The eruption has been called the biggest geophysical event of the century in terms of potential climatic impact. Three months after the eruption, the plume was observed over Laramie, Wyoming. An already existing research project there made it possible to observe the early stages in the evolution of both this and the Mount Saint Helens plume of 1980. Balloon soundings from the El Chichon plume produced data that were unobtainable by any other means. The high concentrations of sulfuric acid suggest that this volcano may have a noticeable climatic effect, in contrast to Mount Saint Helens.

The Wyoming project, which has yielded the longest record of in situ stratospheric aerosol observations at a single location, provides fundamental data in developing models of stratospheric aerosols and their effects on global climate.

Smithsonian Institution

National goals for the peaceful uses of space are met by the Smithsonian Institution through a broad program of basic research at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts, and through public exhibits, lectures, and education programs at its National Air and Space Museum (NASM) in Washington. NASM also conducts historical and basic research in space science.

Space Sciences

High-Energy Astrophysics

Research at SAO focused on analyzing scientific data from the two High Energy Astronomy Observatories (*HEAO 1* and *2*). Programs covered a wide range of astronomical topics, including stellar coronas, supernova remnants, globular clusters, binary x-ray systems, normal galaxies, narrow-emission-line galaxies, radio galaxies, BL Lac objects, Seyfert galaxies, quasars, clusters of galaxies, and surveys and identification of galactic and extragalactic x-ray sources.

Analysis of data from the scanning modulation collimator on board *HEAO 1* continued, with the objective of identifying bright x-ray sources with optical objects. A major milestone was completion of the data-reduction phase by merging directories of all mission data for each of 1200 possible x-ray sources. So far, about 240 sources are indicated.

Among results of investigations by *HEAO 2* (also named *Einstein*) were discovery of a new class of x-ray galaxies—"dull galaxies"; development of a classification scheme for galaxies based on x-ray emission, optical morphology, and radio properties; statistical studies of complete samples of quasi-stellar objects (QSOs); evidence for evolution of QSO x-ray luminosity; correlation of x-ray and optical properties of QSOs; determination of cluster x-ray luminosity function; extension of cluster classification schemes; and estimation of the mass of supernova progenitor stars. Most exciting was the discovery of an x-ray pulsar blinking on and off seven times a second in the supernova remnant MSH 15-5(2), which has given new support to the theory that the massive explosion of stars must leave behind compact cores of the original stellar bodies.

Studies of solar and stellar x-ray emission continued to focus on understanding the physics of coronal formation. Indeed, *HEAO 2* observations of various stars—including, in 1982, M dwarf stars—show that all stars along the so-called main sequence and of all luminosities emit x-rays. This ubiquitous nature of x-ray emission is probably due to the general presence of hot coronas.

Balloon Astronomy

Infrared observations from high-altitude balloons were used for imaging and spectroscopy of astronomical objects, such as regions of star formation and the galactic center, and high-resolution spectroscopy of the earth's atmosphere. A balloon-borne telescope was also used to produce a high-resolution far-infrared map of a large area ($1° \times 4°$) of the galactic center.

Geophysics and Geodynamics

SAO continued to operate a satellite laser-tracking network, which provided routine tracking for geophysical research at the observatory and other research organizations in the U.S. and abroad. In addition to tracking, it provided five-day mean pole positions routinely to the scientific community. During the year, the laser tracking stations were closed in Natal, Brazil; Orroral Valley, Australia; and Mount Hopkins, Arizona. Arrangements were made to relocate the laser from Natal to Matera, Italy, under a joint program with the Consiglio Nazionale delle Ricerche.

Studies of the earth's thermosphere based on data from satellite-borne mass spectrometers continued. Data from earlier satellites *ESRO 4* (1972–1974) and *Explorer 12* (1961) were augmented by those from *Explorer 51* (1973–1978), which provided needed information for greater heights. Major emphasis was on the geomagnetic variation in its relation to the heat sources and the dynamics of the disturbed thermosphere. An important result was identification of the effects of winds and waves generated by the heat input and the successful modeling of the time lag and the persistence of disturbance.

Solar and Stellar Physics

Instruments launched aboard a sounding rocket from White Sands Missile Range on 20 July aided study of the generation of the solar wind in the sun's corona. By combining data from two instruments, a new ultraviolet-light coronagraph developed by SAO and a white-light coronagraph from the High Altitude Observatory, the experimenters hope to determine for the first time the velocity of coronal material accelerated into the solar wind. The studies should provide a better understanding of how the sun (and other stars) generate wind and, ultimately, help develop means for predicting solar wind streams and their effects on Earth and other planets.

The *HEAO 2* and International Ultraviolet Explorer (*IUE*) satellites measured high-temperature plasmas in stars. Theoretical calculations of radiative processes in optically thick chromospheric emission lines and other features in static and expanding solar and stellar atmospheres permitted definition of the energy balance required to cool atmospheres.

Gravity Research

SAO's hydrogen maser group continued research and experiments using ultrastable clocks. Experimental work with cryogenically cooled masers investigated hydrogen collision effects on wall surfaces coated with various freezing gases and demonstrated stability at the 10^{-16} level for intervals between one minute and one hour.

The simulation was completed of doppler detection of pulsed low-frequency gravitational waves using such clocks with a multilink doppler system in a deep space probe. With today's precise timing and space tracking technology, it is possible to detect pulses at the 10^{-14} level in the doppler signatures. These pulses are thought to originate in the collapse of supermassive black holes of about 10^7 solar masses, which may exist at the core of some galaxies. This is the first feasible system developed that could detect such waves.

Planetary Science

NASM's Center for Earth and Planetary Studies in 1982 conducted basic research in comparative planetology, lunar geochemistry, and terrestrial remote sensing. Photogeologic studies of features on the moon, Mars, and Mercury indicated that global-scale planetary compression was involved in deformation of early planetary crusts. Geochemical variations detected from lunar orbit by the Apollo x-ray fluorescence experiment have been used to define areas of primitive crustal material.

Terrestrial remote-sensing studies, using Landsat and other orbital data, have shown the value of combining visible-wavelength images with infrared spectra. Scientists investigated desert regions in Saudi Arabia to determine which spectral ratios could best distinguish surface compositional variations. Multispectral reflectivity measurements of samples from the desert surface in Kharga Oasis, Egypt, are being used to calibrate data from the radar and multispectral experiments conducted from the Space Shuttle *Columbia* in November 1981.

History of Space Science

NASM initiated a program to study the developmental history of the *Space Telescope* (ST). The project is designed to complement other efforts evaluating the historical significance of major space programs and will ensure that all important ST records are preserved.

Department of State

International civil space activities of the United States in 1982 focused on the Space Transportation System (Shuttle) program, the Second United Nations Conference on the Exploration and Peaceful Uses of Space (UNISPACE '82), and the development of the Reagan administration's space policy. The United States continued to pursue an expanding program of international cooperation and interaction in its civil space activities. Now in its operational mode, the Space Transportation System will provide increased opportunities for international participation, reimbursable launch services, a more flexible policy on inclusion of foreign payload specialists, and use of the NASA-European Space Agency Spacelab and the Canadian remote manipulator system. International interest continues to grow in land and meteorological remote sensing and especially in the U.S. Landsat program, with several new countries interested in direct-readout ground stations. The Department of State works with NASA, Department of Defense, Office of Science and Technology Policy, National Oceanic and Atmospheric Administration, and National Security Council in formulating U.S. positions on international aspects of space policy.

Issues have ranged from private-sector participation in remote sensing and launch services to the restructuring of the planetary exploration programs; from the use of the geostationary orbit to direct television broadcasting from space and the maintenance of the longstanding U.S. policy of nondiscriminatory availability to the public of data from federal civil remote-sensing satellites. Foreign demand for space-related products and services from the U.S. private sector has continued to grow, with the support of the Department of State within the guidelines of national security and foreign policy.

The department, in addition to coordinating U.S. efforts for UNISPACE '82, carried out its regular responsibilities in the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), the United Nations General Assembly, the International Telecommunications Satellite Organization (INTELSAT), and International Maritime Satellite Organization (INMARSAT).

Activities within the United Nations

Outer Space Committee

The United Nations Committee on the Peaceful Uses of Outer Space is a forum and negotiating body for international space law and consideration of aspects of international cooperation in space activities. Through this committee the international community is building a foundation for cooperation on legal, political, and technical issues. The United States plays a leading role in the committee and its two subcommittees, the Scientific and Technical Subcommittee and the Legal Subcommittee. State, NASA, NOAA, DoD and other U.S. agencies are represented at the meetings of the committee and the subcommittees. Because of the special interest in the Shuttle flights, the United States hosted many heads of foreign delegations to the launching of the third and fourth Shuttle flights and the administrator of NASA delivered a speech to the Outer Space Committee at the end of the successful third flight. Issues before the committee in 1982, as in the recent past, were draft principles governing direct television broadcasting by satellites, draft principles for remote sensing of the earth, definition of outer space, use of the geostationary orbit, and preparation for UNISPACE '82.

UNISPACE '82

The United States participated from 1980 in planning the UNISPACE '82 Conference. The conference was held in Vienna 9-21 August 1982, with 94 countries and more than 30 international organizations represented. The U.S. delegation, led by the administrator of NASA, included senior government officials, leaders of the aerospace industry, congressional members, and private citizens. With substantial participation by the private sector, the U.S. staged an exhibition of space technology and demonstrations. In addition, the U.S. announced several initiatives planned in space science and applications to advance international cooperation. The principal product of the conference was its final report, a consensus document that covers the exploration and peaceful uses of outer space and incorporates many recommendations for future study by the United Nations and its specialized agencies. The report's emphasis reflects the goal of the conference: to advance the benefits of space technology to developing countries.

U.N. General Assembly

The 37th session of the General Assembly in December adopted by a vote of 88 to 15 (including U.S.), with 11 abstentions, a resolution on principles governing the use by states of satellites for direct television broadcasting. The resolution was a significant departure from the U.N.'s traditional consideration of issues related to peaceful uses of outer space in that it was forced to a vote despite lack of consensus on the principles. The United States could not agree with the resolution primarily because of the limitations it contained on the free flow of information.

Communications Satellites

Space communications continues to be the most commercially oriented space application to date. Activities of INTELSAT and INMARSAT have continued to grow, with strong support of the U.S. government, while U.S. industry is the dominant supplier of communications satellites to the world community. The Space Shuttle will continue the tradition of reimbursable launch services.

INTELSAT traffic has continued to grow, with the United States the dominant user. A U.S. firm was awarded the contract for design and construction of the Intelsat VI series, the next generation of INTELSAT satellites. Intelsat VI spacecraft will be compatible with the Shuttle, and significant use of the Shuttle is planned in the program. Intelsat V and V-A satellites, also built by a U.S. manufacturer and launched by NASA, are operating successfully. INTELSAT is studying ways to improve its ability to provide domestic service to developing countries and is also studying future business communication services that will affect INTELSAT traffic demand.

The INMARSAT organization is now operating and includes in its global satellite network the commercial capacity of the Marisat satellites. (See also Federal Communications Commission chapter.)

Arms Control and Disarmament Agency

The U.S. Arms Control and Disarmament Agency conducts a number of activities related to outer space. It contributes to the formulation and implementation of U.S. space policy, conducts and coordinates research on outer space arms control, participates in international discussions concerning outer space arms control, and promotes the principles of peaceful exploration and use of outer space by all nations for the benefit of mankind, consistent with national space policy.

Space Policy

ACDA participated in the formulation of the administration's new space policy announced by the president on 4 July 1982. This policy reinforces and clarifies the government's oft-stated goal of exploiting the potential of outer space for enhancing the security and welfare of mankind. It provides that the United States will continue to study space arms control options and will consider verifiable and equitable arms control measures that would ban or limit development and testing of specific weapon systems, consistent with U.S. national security.

The director of ACDA, as a member of the Senior Interagency Group (SIG) on Space established by the policy directive, participates in this process. The SIG mandate is to advise on proposed changes in national space policy and to refer space policy issues to the president for decision as necessary.

Multilateral Discussions on Space Arms Control

The Geneva-based Committee on Disarmament discussed outer space arms control at both its spring and summer sessions in 1982. The committee had before it two resolutions passed the previous year by the United Nations General Assembly on possible negotiations toward further arms control measures affecting outer space. There was considerable interest in and discussion of the subject, but the committee to date has taken no decision on how it might treat the question or whether negotiations might be pursued. ACDA has the principal responsibility for staffing and supporting the U.S. delegation to the committee, as well as to the U.N. General Assembly's First Committee, which deals with disarmament issues.

UNISPACE '82

ACDA participated in the U.N.-sponsored Conference on Exploration and Peaceful Uses of Outer Space in Vienna in August 1982, where a number of countries insisted on discussing arms in space, although the issue was not on the agenda. The U.S. delegation, consisting of persons from both the government and the private sector, stressed the extent of international cooperation in space—the U.S. has more than 1000 agreements with more than 100 countries—and the efforts being made to bring benefits to all peoples of the earth. The U.S. proposed a U.N. working group on disaster assistance communications, a U.S.-sponsored 1984 conference on global disaster monitoring and early warning, and a U.S.-sponsored 1985 conference on rural satellite communications.

Space Conference

ACDA and NASA cosponsored a symposium in Washington in September commemorating the 15th anniversary of the Outer Space Treaty of 1967. Senior officials from government, industry, and academe discussed the role of the treaty in promoting international order in the use of outer space, as well as future activities in space and the U.S. space program. The featured speakers were Judge William Clark, the president's national security adviser; Senator Harrison Schmitt, Apollo astronaut; Administrator James Beggs of NASA; Director Eugene Rostow of ACDA; and astronaut Joe Engle, NASA.

United States Information Agency

Telling the world about the United States role in the exploration and peaceful uses of space has been a continuing topic of the U.S. Information Agency, and 1982 proved another rich year of space achievement. USIA coverage included direct satellite TV and live radio broadcasts, news coverage and feature stories, interviews, exhibits, visits of astronauts to overseas posts, and video tape programs for television. The continuing series of flights by the Space Shuttle *Columbia* was the most important space story, but the agency also supported U.S. participation in the 1982 U.N. Conference on the Peaceful Uses of Space (UNISPACE '82). USIA emphasized the U.S. commitment to advancing science and enlarging the frontiers of human knowledge through the peaceful exploration of space, stressing U.S. leadership and the spin-off benefits for mankind.

Space Shuttle

USIA correspondents were on the scene at the launch of *Columbia*'s third, fourth, and fifth flights, at the landings, and at mission control in Houston. Coverage was extensive and detailed. Voice of America broadcast live in Chinese, Polish, Dari Portuguese, Russian, and Spanish, to name a few of the languages in which the event was covered. The Wireless File, USIA's press service to 193 posts in 125 countries, included preliminary and on-the-spot coverage of the launches as well as supplemental features about the astronauts, the cargo, and the uses of new technology. The file also reported on international cooperation, as in the use of the Canadian-built remote manipulator arm and the arrangements with Senegal for using the Dakar airport as abort site.

Agency magazines featured stories on the Space Shuttle. *Span,* the agency's award-winning monthly publication in India, included several. A packet of pictures for each of the Shuttle flights and a special feature packet, "Columbia's Triumph: The Future in Space," were shipped to all field posts.

The USIA television service produced a series on the Shuttle, including a half-hour feature program in Arabic, French, Spanish, and Portuguese, as well as English. USIA news clips on the missions dealt with astronaut training, payload, astronaut profiles, and flight overviews.

Agency exhibits on *Columbia* were popular again during 1982. Posts in Japan, Canada, and India produced major exhibits, and Shuttle-related materials as well as materials on past NASA projects were sent to nearly 30 field posts worldwide. Shuttle tile displays as well as moon rocks were circulated to posts. The agency also cooperated with a number of foreign institutions in exhibits on space themes and is producing a poster exhibit entitled "Deep Space," featuring a number of research projects coordinated by NASA.

Face-to-face meetings with U.S. astronauts have been an important element of information transfer for foreign scientists, government officials, academics, and citizens; and in 1982 USIA continued to program astronaut visits. Six astronauts visited 13 countries, and evaluations of the visits noted an improved understanding of U.S. space efforts and strengthened relations with the United States following each visit.

UNISPACE '82

The Second United Nations Conference on the Peaceful Uses of Outer Space also was extensively covered by USIA. The agency provided policy guidance on the conference to all its posts. Coverage included Voice of America interviews with NASA Administrator James Beggs, astronauts Henry Hartsfield and Anna Fisher, and UNISPACE Deputy Secretary General Jerry Grey. VOA broadcast daily reports from Vienna on the conference along with feature stories on special items.

The Wireless File carried a series of articles summarizing the U.S. contribution to the exploration of space, including the use of satellites for communications, remote sensing, and weather; planetary and interplanetary vehicles and experiments; the space telescope; and the future of man in space. The File also provided foreign print media with an exclusive interview with Administrator Beggs as well as the text of his address at the conference and a White House Fact Sheet on space policy. For the conference, the agency produced a four-color poster-pamphlet in English, German, French, and Spanish on the Space Shuttle and benefits of the U.S. space program. Agency distribution of the item is continuing through 1982 and 1983.

Other Programs

USIA also covered various satellite launches during 1982 and produced interviews with NASA researchers and technicians on topics from extraterrestrial life to astrophysics. These were sent to field posts and broadcast by VOA. Feature articles on the launch of *Insat 1A*—which provides weather forecasting, telecommunications, and direct television broadcasting for the United States—appeared in agency magazines throughout the world. VOA produced several scripts and documentaries on U.S. planetary probes, the search for extraterrestrial intelligence (SETI), the industrialization of space, and the establishment of space stations. VOA also observed the 25th anniversary of Sputnik and the 100th anniversary of the birth of Robert Goddard. It interviewed Arthur Clarke on the future in space and prepared a documentary on his thoughts.

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
Total	998	134	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 Launchings Successful in Attaining Earth Orbit or Beyond

(Enumerates launchings 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	97			3	1			2	2
1982	18	101			1	1				
Total	792	1537	10	8	21	10	1	1	3	3

[a] Includes foreign launchings of U.S. spacecraft.

Successful U.S. Launches—1982

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
16 Jan. *RCA-Satcom 4* 4A Thor-Delta	Objective: To place spacecraft in stationary geosynchronous orbit to transmit television, voice channels, and high-speed data to Alaska, Hawaii, and contiguous U.S.; to provide video programming to CATV (cable television) systems throughout U.S. Spacecraft: Box-shaped 1.2 × 1.2 × 1.6 m high; 2 rectangular solar panels on short booms. Hydrazine-propellant tanks protrude from east and west panels of spacecraft body. Three-axis stabilized. Weight at launch: 1082 kg.	35 795 35 778 1436.1 0.0	Fifth in a series of RCA commercial, domestic communications satellites launched by NASA into transfer orbit. Apogee-kick motor fired 19 Jan., placing satellite in geosynchronous orbit at 83° W. longitude.
21 Jan. Defense 6A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	641 630 97.4 97.2	Reentered 23 May 1982.
26 Feb. *Westar 4* 14A Thor-Delta	Objective: To launch spacecraft into synchronous-transfer orbit. Satellite to transmit television, voice, and facsimile data throughout continental U.S., Alaska, Hawaii, Puerto Rico, and Virgin Islands. Spacecraft: Drum-shaped telescoping cylinder 2.8 m high in stowed configuration, and 6.6 m when deployed in space; 2.2 m in diameter; spin-stabilized. Carries 24 color TV channels, twice previous Westar spacecraft, design life of 10 yrs. Weight in orbit after apogee motor firing: 1072 kg.	35 790 35 785 1436.2 0.0	First in a series of second-generation satellites; launched by NASA for Western Union Telegraph Company. Apogee-boost motor fired 1 Mar., placing satellite in stationary synchronous orbit at 99° W. longitude, as replacement for *Westar 1* launched in 1974.
5 Mar. Intelsat V F-4 17A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 12 000 voice circuits plus 2 color TV channels simultaneously. Spacecraft: Modular main body, 1.66 × 2.01 × 1.77 m, with winglike solar arrays spanning 15.6 m. Overall height, 6.4 m; width deployed, 6.8 m; 6 communications antennas—2 global-coverage horns, 2 hemispherical/zone offset-fed reflectors, and 2 offset-fed spot-beam reflectors. Double the capacity of Intelsat IV-A series. Weight at launch: 1928 kg.	35 798 35 778 1436.2 0.1	Fourth in series of 9 satellites; launched by NASA for 106-member-nation International Telecommunications Satellite Organization (INTELSAT). Placed in geosynchronous orbit after apogee-motor firing 7 Mar.; positioned above Indian Ocean to provide communication services between Europe, Middle East, and Far East.
6 Mar. Defense 19A Titan IIIC	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	35 797 35 786 1436.4 1.5	Still in orbit.
22 Mar Space Shuttle *Columbia* (STS 3) 22A	Objective: To demonstrate ascent, in-orbit, and entry performance under conditions more demanding than in STS 2; extend orbital flight duration; conduct long-duration thermal-soak tests; and conduct scientific and applications research with attached Office of Space Science payload (OSS 1). Space Shuttle consists of reusable orbiter *Columbia* (OV-102), external tank (ET), and 2 solid-fueled rocket boosters (SRBs). Orbiter is crew- and payload-carrying, delta-winged spacecraft about size of DC-9 aircraft, 37 m long with 24-m wing span, weighing 75 000 kg without fuel. Orbiter designed to transport payload of 29 500 kg into orbit when operational. Cargo bay measures 18.3 × 4.6 m. Three main, liquid-fueled rocket engines, each with 1670-kilonewton thrust at sea level. Engines fed propellants from external tank 47 m long, 8.4 m in diameter, holding 719 000 kg liquid hydrogen and liquid oxygen. External tank,	247 239 89.4 38.0	NASA's 3d of 4 planned flight tests of Space Transportation System. *Columbia*, piloted by astronauts Jack R. Lousma and C. Gordon Fullerton, lifted off from KSC at 11:00 a.m. EST. *Columbia* was put through extensive thermal testing in various attitudes. OSS 1 pallet returned scientific data. Remote manipulator system (RMS) moved plasma experiment outside Shuttle cargo bay. Flight extended 1 day because heavy rains flooded normally dry lake-bed runways at Edwards AFB, Calif. Alternate landing site, Northrop strip at White Sands, New Mex., saw touchdown of *Columbia* at 11:05 a.m. EST, 30 Mar. Crew left orbiter 45 min. after landing.

Successful U.S. Launches—1982

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
	only part of Shuttle not reusable, was jettisoned just before orbit. Solid-fueled rocket boosters—each 45.5 m long, 3.8 m in diameter, with 23 575-kilonewton combined thrust—dropped away after ascent for recovery and reuse. Payload: OSS 1 payload consisted of 9 separate investigations: plasma diagnostics package (PDP), vehicle charging and potential (VCAP), Spacelab induced atmosphere (SIA), thermal canister experiment (TCE), solar-flare x-ray polarimeter (SFXP), solar-ultraviolet spectral-irradiance monitor (SUSIM), influence of weightlessness on lignification in developing plant seedlings (PGU), microabrasion foil experiment (MFE), and contamination monitor package (CMP). Additional payloads and instrument included getaway special flight-verification payload, monodisperse latex reactor, heflex bioengineering test, orbital flight-test pallet, induced-environment-contamination monitor, and Shuttle student-involvement project. Remote manipulator system (RMS) was carried on this flight.		Total mission time: 8 days 4 hrs 49 min. *Columbia* returned to KSC 3:58 p.m. EST, 6 Apr., to begin processing for STS 4 mission.
10 Apr. *Insat 1A* 31 A Thor-Delta	Objective: To launch satellite into transfer orbit with sufficient accuracy to permit spacecraft to be placed in stationary synchronous orbit. Satellite to provide nationwide direct broadcasting to community TV receivers in rural areas of India. Spacecraft: Rectangular main body 1.42 x 1.55 x 2.18 m. In orbit, with solar sail and solar array deployed, 19.4 m wide. Additional instrumentation includes a very-high-resolution radiometer (VHRR) for meteorological observations. Three-axis stabilized. Weight: 1152 kg.	37 167 34 395 1435.9 0.5	First in series of communications satellites; launched by NASA for the India Department of Space (DOS). Apogee-boost motor fired successfully 11 and 12 Apr. Satellite was maneuvered to 74° E. longitude, but met operational problems; it failed in September because all of attitude-control-system propellant was consumed.
11 May Defense 41A Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	251 157 88.6 96.3	Still in orbit.
9 June *Westar 5* 58A Thor-Delta	Objective: To launch spacecraft into suborbital trajectory of sufficient accuracy to permit payload propulsion system to place it in stationary synchronous orbit. Satellite to relay voice, data, video, and facsimile communications to U.S., Hawaii, Alaska, Puerto Rico, and Virgin Islands. Spacecraft: Telescoping cylinder 2.8-m high in stowed configuration, and 6.6-m when deployed in space; 2.2-m in diameter; spin-stabilized. Carries 24 color TV channels, twice previous Westar spacecraft, design life of 10 yrs. Weight in orbit after apogee motor fire: 1072 kg.	35 795 35 777 1436.1 0.0	Second in a series of second-generation satellites; launched by NASA for Western Union Telegraph Company. Apogee-boost motor fired 11 June; satellite placed in stationary synchronous orbit at 75° W. longitude, replacing *Westar 2*.
27 June Space Shuttle *Columbia* (STS 4) 65A	Objective: To demonstrate ascent, in-orbit, and entry performance under conditions more demanding than in STS 3; conduct long-duration thermal-soak tests; and conduct scientific and applications research with attached payload. Space Shuttle; see Mar. 22. Payload: Continuous-flow electrophoresis system, commercial experiment designed by McDonnell Douglas Astronautics Co.; monodisperse latex reactor; two	307 297 90.6 28.5	Last flight of NASA's orbital test flight program. Shuttle demonstrated readiness for routine space operations. *Columbia*, piloted by astronauts Thomas K. (Ken) Mattingly II and Henry W. Hartsfield, Jr., lifted off from KSC at 11:00 a.m. EST. Scientific payload returned valuable data. *Columbia* touched down on runway 22

Successful U.S. Launches—1982

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
	medical experiments of the Shuttle student-involvement project; first get-away special; nighttime/daylight optical survey of lightning. Induced-environment-contamination monitor (IECM) was moved about payload bay area by remote manipulator system (RMS). Shuttle also carried Department of Defense payload.		at Edwards AFB, Calif., 12:09 p.m. EDT, 4 July. President Reagan, at landing ceremonies, declared Space Transportation System operational. Shuttle's solid-fueled rocket boosters sank in Atlantic Ocean; not recovered for reuse. Total mission time: 7 days 1 hr 9 min. *Columbia*, ferried aboard 747 aircraft, arrived at KSC 15 July to begin processing for STS 5 mission.
16 July Landsat 4 72A Thor-Delta	Objective: To acquire multispectral imagery sufficient to improve remote-sensing interpretive techniques and test new instrument, thematic mapper (TM), for at least 1 year. Spacecraft: Main spacecraft body consists of multimission modular spacecraft (MMS) and instrument module (IM); high-gain antenna mounted at end of 4-m mast for Tracking and Data Relay Satellite System (TDRSS) communications, single-wing solar array. Principle instruments are thematic mapper and multispectral scanner (MSS), both in instrument module. Weight: 1942 kg.	701 697 98.8 98.2	Launched by NASA into circular, near-polar sun-synchronous orbit, permitting spacecraft to photograph entire globe every 16 days, in 185-km swaths. Followed *Landsat 1* launched in 1972, *Landsat 2* in 1975, and *Landsat 3* in 1978. All systems activated as of 18 July and performing well. MSS and TM providing excellent imagery at end of year.
26 Aug. *Anik D-1* (Telesat-G) 82A Thor-Delta	Objective: To launch satellite into transfer orbit permitting spacecraft propulsion system to place it in stationary synchronous orbit for communications coverage over Canada. Spacecraft: Launch configuration 2.2 m in diameter by 2.8 m high, cylindrical. In orbit, satellite deployed to height of 6.6 m. Spin-stabilized. Weight after apogee-kick-motor firing: 730 kg.	35 793 35 781 1436.1 0.0	Launched by NASA for Telesat Canada as in-orbit replacement for 3 aging Anik-A (1972, 1973, 1975) and 1 Anik-B (1978) satellites. Apogee-boost motor fired 29 Aug. Satellite on station at 104° W. longitude.
28 Sept. *Intelsat V F-5* 97A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 12 000 voice circuits and 2 color TV channels simultaneously. Spacecraft: Modular main body, 1.7 x 2 x 1.8 m, with winglike solar arrays spanning 15.6 m. Overall height, 6.4 m; width deployed, 6.8 m; 6 communications antennas—2 global-coverage horns, 2 hemispherical/zone offset-fed reflectors, and 2 offset-fed spot-beam reflectors. Double the capacity of Intelsat IV-A series. Maritime communications services (MCS) package for International Maritime Satellite Organization (INMARSAT) to provide ship-shore-ship communication. Weight at launch: 2000 kg.	35 797 35 769 1435.9 1.4	Fifth in series of 9 satellites; launched by NASA for 106-member-nation International Telecommunications Satellite Organization (INTELSAT). Placed in geosynchronous orbit after apogee-motor firing 1 Oct.; positioned over Indian Ocean at 63° E. longitude.
27 Oct. *RCA-Satcom 5* 105A Thor-Delta	Objective: To place spacecraft in stationary geosynchronous orbit to provide TV, voice channels, and high-speed data transmission to Alaska, Hawaii, and contiguous U.S. and provide video programming to CATV (cable television) systems throughout U.S. Spacecraft: Box-shaped 1.2 x 1.2 x 1.6 m high; 2 rectangular solar panels on short booms give satellite span of 15.8 m. Hydrazine-propellant tanks protrude from east and west panels of spacecraft body. Three-axis stabilized. Weight in orbit: 589.5 kg.	35 810 35 764 1436.1 0.1	Communications satellite launched by NASA for RCA joined 4 other RCA satellites—*Satcom 1, 2, 3-R,* and *4*—in orbit. Apogee-kick motor fired 30 Oct., placing satellite over Pacific Ocean at 143° W. longitude.
30 Oct. DSCS II satellite 106A Titan III(34)D/IUS	Objective: To place Defense Satellite Communications Systems II spacecraft in geosynchronous orbit. Spacecraft: Barrel-shaped. Dimensions and weight not announced.	35 776 35 644 1432.2 2.4	Dual launched by Air Force with DSCS III satellite. First Use of Titan(34)D with inertial upper stage (IUS) to launch spacecraft. Still in orbit.

Successful U.S. Launches—1982

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (%)	Remarks
DSCS III satellite 106B	Objective: To place Defense Satellite Communications Systems III spacecraft in geosynchronous orbit. Spacecraft: Central body 2.8 m long, 7.6 m wide, 2 m in diameter. With solar array fully extended, length 1.2 m. Satellite 3-axis stabilized. Weight (dry): 816.4 kg.	35 857 35 727 1436.4 2.4	Dual launch by Air Force with DSCS II satellite. First in series of uprated communications satellites. Still in orbit.
11 Nov. Space Shuttle *Columbia* (STS 5) 110A	Objective: To demonstrate initial operational capability by launching 2 commercial communications satellites and demonstrate extravehicular activity (EVA) capability. Payload: Two commercial communication satellite; also instrument packages composed of development flight instrumentation (DFI), aerodynamic coefficient identification package (ACIP); student experiments—growth of porifera in zero gravity, formation of crystals in weightlessness, and convection in zero gravity; getaway special (GAS); NASA experiments—monodisperse latex reaction (MLR), tile gap heating effects, catalytic surface effects, dynamic, acoustic and thermal environment (DATE), and atmospheric luminosities investigation (Glow experiment).	302 276 90.3 28.5	NASA flew first operational flight of Space Transportation System. *Columbia* was piloted by astronauts Vance D. Brand and Robert F. Overmyer. Mission specialists: Joseph P. Allen and William B. Lenoir. Shuttle lifted off from Launch Complex 39, Pad A, at 7:00 a.m. EST. Two satellites were launched from payload cargo bay. EVA canceled when problems developed in both spacesuits. *Columbia* landed on concrete runway at Edwards AFB, Calif., 9:33 a.m. EST, 16 Nov. Total mission time: 5 days 2 hrs 14 min 25 sec. Orbiter returned to KSC 22 Nov. for major overhaul and refurbishment for next scheduled flight in fall 1983 (STS 9).
SBS 3 110B	Objective: To launch first commercial communications satellite from Shuttle. Spacecraft to provide integrated, all-digital, interference-free transmission of telephone, computer, electronic mail, and video teleconferencing to SBS business clients. Spacecraft: Cylindrical, 2.2 m in diameter, with stowed height at launch of 2.8 m; height in orbit, 6.6 m with solar panel and antenna deployed. Spin-stabilized. Weight: 601.5 kg.	35 790 35 786 1436.2 0.0	First satellite launch from Shuttle cargo payload bay of Space Transportation System. Satellite Business Systems. *SBS 3* was released at 3:17 p.m. EST, 11 Nov. Payload assist module (PAM-D) fired 45 minutes later, boosting satellite to geosynchronous-transfer orbit and finally into geosynchronous orbit at 94° W. longitude.
Anik C-3 (Telesat 5) 110C	Objective: To launch commercial communications satellite from Shuttle. Spacecraft: Cylindrical, 2.2 m in diameter, with stowed height at launch of 2.8 m; height in orbit, 6.6 m with solar panel and antenna deployed. Spin-stabilized. Weight: 632.3 kg.	35 796 35 778 1436.1 0.0	Second commercial satellite launch from Shuttle, *Anik C-3* was deployed by NASA for Telesat Canada at 3:24 p.m. EST, 12 Nov. Satellite stationed at 117.5° W. longitude.
17 Nov. Defense 111A Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	474 268 92.0 97.0	Still in orbit.
21 Dec. DMSP satellite 118A Atlas E	Objective: To launch meteorological observation satellite into planned orbit. Spacecraft: Same basic configuration as *NOAA 7*. Weight: 753 kg.	823 811 101.2 98.7	Defense Meterological Satellite Program block 5D2 spacecraft. Still in orbit.

U.S.-Launched Applications Satellites 1977-1982

Date	Name	Launch Vehicle	Remarks
		COMMUNICATIONS	
28 Jan. 1977	NATO IIIB	Thor-Delta (TAT)	Second of new series.
10 Mar. 1977	Palapa 2	Thor-Delta (TAT)	Indonesian domestic communications.
12 May 1977	DSCS II-7,8	Titan IIIC	Defense communications (dual launch).
26 May 1977	Intelsat IVA F-4	Atlas-Centaur	Positioned over Atlantic.
25 Aug. 1977	Sirio	Thor-Delta (TAT)	Italian experiment.
15 Dec. 1977	Sakura	Thor-Delta (TAT)	Japanese experiment.
7 Jan. 1978	Intelsat IVA F-3	Atlas-Centaur	Positioned over Indian Ocean.
9 Feb. 1978	Fltsatcom 1	Atlas-Centaur	First of new Defense series.
5 Mar. 1978	Oscar 8	Thor-Delta (TAT)	Secondary payload with Landsat 3, replacement for Oscar 6 for amateur radio communications.
31 Mar. 1978	Intelsat IVA F-6	Atlas-Centaur	Positioned over Indian Ocean.
7 Apr. 1978	BSE (Yuri)	Thor-Delta (TAT)	Japanese experimental direct-broadcast satellite for television; domestic satellite.
11 May 1978	OTS 2	Thor-Delta (TAT)	European Space Agency experimental relay satellite; domestic satellite.
29 June 1978	Comstar D-3	Atlas-Centaur	Positioned south of U.S. over the equator by Comsat; domestic satellite.
19 Nov. 1978	NATO IIIC	Thor-Delta (TAT)	Final one of this military series.
14 Dec. 1978	DSCS II-11,12	Titan IIIC	Defense communications (dual launch).
16 Dec. 1978	Anik 4 (Telesat D)	Thor-Delta (TAT)	Launched for Canada; domestic satellite.
4 May 1979	Fltsatcom 2	Atlas-Centaur	Second of new DoD series.
9 Aug. 1979	Westar 3	Thor-Delta (TAT)	Launched for Western Union Co. as part of its domestic communications links.
21 Nov. 1979	DSCS II-13,14	Titan IIIC	Defense communications (dual launch).
2 Dec. 1979	RCA-Satcom 3	Thor-Delta (TAT)	Launched for RCA, but contact lost during orbit circularization.
18 Jan. 1980	Fltsatcom 3	Atlas-Centaur	Third of DoD series.
31 Oct. 1980	Fltsatcom 4	Atlas-Centaur	Fourth of DoD series.
15 Nov. 1980	SBS 1	Thor-Delta (TAT)	Launched for Satellite Business Systems as part of its domestic communications links.
6 Dec. 1980	Intelsat V F-2	Atlas-Centaur	First of new series, positioned over Atlantic.
21 Feb. 1981	Comstar D-4	Atlas-Centaur	Fourth in series for Comsat General Corp.
23 May 1981	Intelsat V F-1	Atlas-Centaur	Second in series for INTELSAT, positioned over Atlantic.
6 Aug. 1981	Fltsatcom 5	Atlas-Centaur	Fifth in DoD series.
24 Sept. 1981	SBS 2	Thor-Delta (TAT)	Second in series for Satellite Business Systems.
20 Nov. 1981	RCA-Satcom 3-R	Thor-Delta (TAT)	Fourth in series for RCA, replacement for RCA-Satcom 3.
15 Dec. 1981	Intelsat V F-3	Atlas-Centaur	Third in series. To be positioned over Atlantic.
16 Jan. 1982	RCA-Satcom 4	Thor-Delta (TAT)	Fifth in series for RCA.
26 Feb. 1982	Westar 4	Thor-Delta (TAT)	First in a series of second-generation for Western Union Co.
5 Mar. 1982	Intelsat V F-4	Atlas-Centaur	Fourth in series; positioned over Pacific.
10 Apr. 1982	Insat 1A	Thor-Delta (TAT)	First in series for India Department of Space.
9 June 1982	Westar 5	Thor-Delta (TAT)	Second in series of second-generation for Western Union Co.; replaces Westar 2.
26 Aug. 1982	Anik D-1	Thor-Delta (TAT)	Launched for Telesat Canada as replacement for in-orbit satellites.
28 Sept. 1982	Intelsat V F-5	Atlas-Centaur	Fifth in series; positioned over Indian Ocean.
27 Oct. 1982	RCA-Satcom 5	Thor-Delta (TAT)	Joined 4 operational satellites launched for RCA.
30 Oct. 1982	DSCS II, DSCS III	Titan III(34) D/IUS	Defense communications (dual launch), including first in series of uprated satellites.
11 Nov. 1982	SBS 3	Space Shuttle, PAM-D	Third in series for Satellite Business Systems.
12 Nov. 1982	Anik C-3	Space Shuttle, PAM-D	Second in new series for Telesat Canada.
		WEATHER OBSERVATION [a]	
16 June 1977	GOES 2	Thor-Delta (TAT)	Second in series of operational synchronous-orbit satellites for NOAA.
14 July 1977	Himawari	Thor-Delta (TAT)	Japanese geosynchronous satellite.
23 Nov. 1977	Meteosat	Thor-Delta (TAT)	European Space Agency geosynchronous satellite.
1 May 1978	AMS 3	Thor-Burner 2	DoD meteorological satellite.
16 June 1978	GOES 3	Thor-Delta (TAT)	Third of this series for NOAA.
13 Oct. 1978	Tiros-N	Atlas F	First of third-generation for NOAA, also experimental satellite for NASA.
24 Oct. 1978	Nimbus 7	Thor-Delta (TAT)	Last of this experimental series for NASA.
6 June 1979	AMS 4	Atlas F	DoD meteorological satellite.
27 June 1979	NOAA 6	Atlas F	Second of 8 planned third-generation satellites for NOAA; first was Tiros-N.
29 May 1980	NOAA-B	Atlas F	Failed to achieve useful orbit.
9 Sept. 1980	GOES 4	Thor-Delta (TAT)	Fourth of this series for NOAA.
22 May 1981	GOES 5	Thor-Delta (TAT)	Fifth of polar-orbiting series for NOAA.
23 June 1981	NOAA 7	Atlas F	Replacement for Noaa-B.
21 Dec. 1982	DMSP	Atlas E	DoD meterological satellite.

[a] Does not include Department of Defense weather satellites that are not individually identified by launch.

APPENDIX B-1—Continued

U.S.-Launched Applications Satellites 1977-1982

Date	Name	Launch Vehicle	Remarks
			EARTH OBSERVATION
5 Mar. 1978	Landsat 3	Thor-Delta (TAT)	Third experimental earth resources satellite.
26 Apr. 1978	HCMM (AEM 1)	Scout	Experimental, low-cost, limited-function heat-capacity mapping mission for earth resources.
27 June 1978	Seasat 1	Atlas F	Proof-of-concept oceanographic-phenomena data-collection satellite.
16 July 1982	Landsat 4	Thor-Delta (TAT)	Fourth experimental earth resources satellite. First use of thematic mapper (TM).
			GEODESY
9 Apr. 1975	Geos 3	Thor-Delta (TAT)	To measure geometry and topography of ocean surface.
4 May 1976	Lageos	Thor-Delta (TAT)	Laser geodynamic satellite.
			NAVIGATION
23 June 1977	NTS 2	Atlas F	Forerunner of Navstar Global Positioning System.
28 Oct. 1977	Transit	Scout	Developmental model.
22 Feb. 1978	Navstar 1	Atlas F	Global Positioning System satellite.
13 May 1978	Navstar 2	Atlas F	Global Positioning System satellite.
7 Oct. 1978	Navstar 3	Atlas F	Global Positioning System satellite.
11 Dec. 1978	Navstar 4	Atlas F	Global Positioning System satellite.
9 Feb. 1980	Navstar 5	Atlas F	Global Positioning System satellite.
26 Apr. 1980	Navstar 6	Atlas F	Global Positioning System satellite.
15 May 1981	Nova 1	Scout	First of improved Transit system satellites, for DoD.

APPENDIX B-2

U.S.-Launched Scientific Satellites 1977-1982

Date	Name	Launch Vehicle	Remarks
20 Apr. 1977	Geos	Thor-Delta (TAT)	European Space Agency, study of magnetic and electric fields from geosynchronous orbit (not attained).
12 Aug. 1977	Heao 1	Atlas-Centaur	X-ray and gamma-ray astronomy.
22 Oct. 1977	ISEE 1,2	Thor-Delta (TAT)	Magnetosphere and solar wind measurements (for NASA and European Space Agency respectively).
26 Jan. 1978	IUE	Thor-Delta (TAT)	Ultraviolet observation of astronomical phenomena, in elliptical geosynchronous orbit.
14 July 1978	Geos 2	Thor-Delta (TAT)	European studies of magnetosphere, in geosynchronous orbit.
12 Aug. 1978	ISEE 3	Thor-Delta (TAT)	International Sun-Earth Explorer, in halo orbit near Earth-Sun libration point.
24 Oct. 1978	Cameo	Thor-Delta (TAT)	Barium and lithium cloud experiments, carried in rocket body of Nimbus 7 launcher.
13 Nov. 1978	Heao 2	Atlas-Centaur	High-resolution observations of astronomical x-ray sources.
30 Jan. 1979	Scatha	Thor-Delta (TAT)	Measurement of sources of electric charge buildup on spacecraft.
18 Feb. 1979	Sage	Scout	Measurement of stratospheric aerosols and ozone.
24 Feb. 1979	Solwind	Atlas F	Measurement of solar wind, electron buildup in polar regions, aerosols, and ozone.
6 June 1979	Ariel 6	Scout	Measurement of cosmic radiation (United Kingdom payload).
20 Sept. 1979	Heao 3	Atlas-Centaur	Gamma and cosmic ray emissions.
30 Oct. 1979	Magsat	Scout	Detailed current description of earth's magnetic field and of sources of variations.
14 Feb. 1980	SMM	Thor-Delta (TAT)	Solar Maximum Mission.
3 Aug. 1981	Dynamics Explorers 1, 2	Thor-Delta (TAT)	DE 1 and 2 to measure magnetospheric-ionospheric energy coupling, electric currents and fields, plasmas.
6 Oct. 1981	SME	Thor-Delta (TAT)	Solar Mesosphere Explorer to measure changes in mesospheric ozone.
6 Oct. 1981	UOSAT (Oscar 9)	Thor-Delta (TAT)	Secondary payload with SME, for amateur radio and science experiments.

U.S.-Launched Space Probes 1975–1982

Date	Name	Launch Vehicle	Remarks
20 Aug. 1975	Viking 1	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Chryse, 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.
9 Sept. 1975	Viking 2	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Utopia, 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.
15 Jan. 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.
20 Aug. 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.
5 Sep. 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.
20 May 1978	Pioneer Venus 1	Atlas-Centaur	Venus orbiter; achieved Venus orbit 4 Dec., returning imagery and data.
8 Aug. 1978	Pioneer Venus 2	Atlas-Centaur	Carried 1 large, 3 small probes plus spacecraft bus; all descended through Venus atmosphere 9 Dec., returned data.

U.S. and Soviet Manned Spaceflights 1961-1982

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Vostok 1	12 Apr. 1961	Yuriy A. Gagarin	0 : 1 : 48	First manned flight.
Mercury-Redstone 3	5 May 1961	Alan B. Shepard, Jr.	0 : 0 : 15	First U.S. flight; suborbital.
Mercury-Redstone 4	21 July 1961	Virgil I. Grissom	0 : 0 : 16	Suborbital; capsule sank after landing; astronaut safe.
Vostok 2	6 Aug. 1961	German S. Titov	1 : 1 : 18	First flight exceeding 24 h.
Mercury-Atlas 6	20 Feb. 1962	John H. Glenn, Jr.	0 : 4 : 55	First American to orbit.
Mercury-Atlas 7	24 May 1962	M. Scott Carpenter	0 : 4 : 56	Landed 400 km beyond target.
Vostok 3	11 Aug. 1962	Andriyan G. Nikolayev	3 : 22 : 25	First dual mission (with Vostok 4).
Vostok 4	12 Aug. 1962	Pavel R. Popovich	2 : 22 : 59	Came within 6 km of Vostok 3.
Mercury-Atlas 8	3 Oct. 1962	Walter M. Schirra, Jr.	0 : 9 : 13	Landed 8 km from target.
Mercury-Atlas 9	15 May 1963	L. Gordon Cooper, Jr.	1 : 10 : 20	First U.S. flight exceeding 24 h.
Vostok 5	14 June 1963	Valeriy F. Bykovskiy	4 : 23 : 6	Second dual mission (with Vostok 6).
Vostok 6	16 June 1963	Valentina V. Tereshkova	2 : 22 : 50	First woman in space; within 5 km of Vostok 5.
Voskhod 1	12 Oct. 1964	Vladimir M. Komarov Konstantin P. Feoktistov Boris G. Yegorov	1 : 0 : 17	First 3-man crew.
Voskhod 2	18 Mar. 1965	Pavel I. Belyayev Aleksey A. Leonov	1 : 2 : 2	First extravehicular activity (Leonov, 10 min).
Gemini 3	23 Mar. 1965	Virgil I. Grissom John W. Young	0 : 4 : 53	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	3 June 1965	James A. McDivitt Edward H. White II	4 : 1 : 56	21-min extravehicular activity (White).
Gemini 5	21 Aug. 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	7 : 22 : 55	Longest-duration manned flight to date.
Gemini 7	4 Dec. 1965	Frank Borman James A. Lovell, Jr.	13 : 18 : 35	Longest-duration manned flight to date.
Gemini 6-A	15 Dec. 1965	Walter M. Schirra, Jr. Thomas P. Stafford	1 : 1 : 51	Rendezvous within 30 cm of Gemini 7.
Gemini 8	16 Mar. 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	3 June 1966	Thomas P. Stafford Eugene A. Cernan	3 : 0 : 21	Extravehicular activity; rendezvous.
Gemini 10	18 July 1966	John W. Young Michael Collins	2 : 22 : 47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	12 Sept. 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	2 : 23 : 17	First initial-orbit docking; first tethered flight; highest earth-orbit altitude (1372 km).
Gemini 12	11 Nov. 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	3 : 22 : 35	Longest extravehicular activity to date (Aldrin, 5 hrs 37 min).
Soyuz 1	23 Apr. 1967	Vladimir M. Komarov	1 : 2 : 37	Cosmonaut killed in reentry accident.
Apollo 7	11 Oct. 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	10 : 20 : 9	First U.S. 3-man mission.
Soyuz 3	26 Oct. 1968	Georgiy T. Beregovoy	3 : 22 : 51	Maneuvered near unmanned Soyuz 2.
Apollo 8	21 Dec. 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	14 Jan. 1969	Vladimir A. Shatalov	2 : 23 : 23	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	15 Jan. 1969	Boris V. Volynov Aleksey S. Yeliseyev Yevgeniy V. Khrunov	3 : 0 : 56	
Apollo 9	3 Mar. 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	18 May 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	16 July 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	11 Oct. 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	12 Oct. 1969	Anatoliy V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4 : 22 : 41	
Soyuz 8	13 Oct. 1969	Vladimir A. Shatalov Aleksey S. Yeliseyev	4 : 22 : 50	

U.S. and Soviet Manned Spaceflights 1961-1982

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Apollo 12	14 Nov. 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 19 Apr. 1967.
Apollo 13	11 Apr. 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	1 June 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17 : 16 : 59	Longest manned spaceflight to date.
Apollo 14	31 Jan. 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	22 Apr. 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 24 Apr. 1971.
Soyuz 11	6 June 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 30 June 1971.
Apollo 15	26 July 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	16 Apr. 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	7 Dec. 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	25 May 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	28 : 0 : 50	Docked with Skylab 1 for 28 days. Repaired damaged station.
Skylab 3	28 July 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	59 : 11 : 9	Docked with Skylab 1 for more than 59 days.
Soyuz 12	27 Sept. 1973	Vasiliy G. Lazarev Oleg G. Makarov	1 : 23 : 16	Checkout of improved Soyuz.
Skylab 4	16 Nov. 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	18 Dec. 1973	Petr I. Klimuk Valentin V. Lebedev	7 : 20 : 55	Astrophysical, biological, and earth resources experiments.
Soyuz 14	3 July 1974	Pavel R. Popovich Yuriy P. Artyukhin	15 : 17 : 30	Docked with Salyut 3 and Soyuz 14 crew occupied space station.
Soyuz 15	26 Aug. 1974	Gennadiy V. Sarafanov Lev S. Demin	2 : 0 : 12	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	2 Dec. 1974	Anatoliy V. Filipchenko Nikolay N. Rukavishnikov	5 : 22 : 24	Test of ASTP configuration.
Soyuz 17	10 Jan. 1975	Aleksey A. Gubarev Georgiy M. Grechko	29 : 13 : 20	Docked with Salyut 4 and occupied station.
Anomaly	5 Apr. 1975	Vasiliy G. Lazarev Oleg G. Makarov	0 : 0 : 20	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	24 May 1975	Petr I. Klimuk Vitaliy I. Sevastyanov	62 : 23 : 20	Docked with Salyut 4 and occupied station.
Soyuz 19	15 July 1975	Aleksey A. Leonov Valeriy N. Kubasov	5 : 22 : 31	Target for Apollo in docking and joint experiments of ASTP mission.
Apollo (ASTP)	15 July 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	6 July 1976	Boris V. Volynov Vitaliy M. Zholobov	48 : 1 : 32	Docked with Salyut 5 and occupied station.
Soyuz 22	15 Sept. 1976	Valeriy F. Bykovskiy Vladimir V. Aksenov	7 : 21 : 54	Earth resources study with multispectral camera system.
Soyuz 23	14 Oct. 1976	Vyacheslav D. Zudov Valeriy I. Rozhdestvenskiy	2 : 0 : 6	Failed to dock with Salyut 5.
Soyuz 24	7 Feb.1977	Viktor V. Gorbatko Yuriy N. Glazkov	17 : 17 : 23	Docked with Salyut 5 and occupied station.
Soyuz 25	9 Oct. 1977	Vladimir V. Kovalenok Valeriy V. Ryumin	2 : 0 : 46	Failed to achieve hard dock with Salyut 6 station.

U.S. and Soviet Manned Spaceflights 1961-1982

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz 26	10 Dec. 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	10 Jan. 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	2 Mar. 1978	Aleksey A. Gubarev Vladimir Remek	7 : 22 : 17	Docked with Salyut 6. Remek was first Czech cosmonaut to orbit.
Soyuz 29	15 June 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	27 June 1978	Petr I. Klimuk Miroslaw Hermaszewski	7 : 22 : 4	Docked with Salyut 6. Hermaszewski was first Polish cosmonaut to orbit.
Soyuz 31	26 Aug. 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	25 Feb. 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	10 Apr. 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	6 June 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	9 Apr. 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	26 May 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	5 June 1980	Yuriy V. Malyshev Vladimir V. Aksenov	3 : 22 : 21	Docked with Salyut 6. First manned flight of new-generation ferry.
Soyuz 37	23 July 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	18 Sept. 1980	Yuriy V. Romanenko Arnaldo Tamayo Mendez	7 : 20 : 43	Docked with Salyut 6. Tamayo was first Cuban to orbit.
Soyuz T-3	27 Nov. 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	12 Mar. 1981	Vladimir V. Kovalenok Viktor P. Savinykh	74 : 18 : 38	Docked with Salyut 6.
Soyuz 39	22 Mar. 1981	Vladimir A. Dzhanibekov Jugderdemidiyn Gurragcha	7 : 20 : 43	Docked with Salyut 6. Gurragcha first Mongolian cosmonaut to orbit.
Space Shuttle Columbia (STS 1)	12 Apr. 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	14 May 1981	Leonid I. Popov Dumitru Prunariu	7 : 20 : 41	Docked with Salyut 6. Prunariu first Romanian cosmonaut to orbit.
Space Shuttle Columbia (STS 2)	12 Nov. 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)	22 Mar. 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.
Soyuz T-5	13 May 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	24 June 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)	27 June 1982	Thomas K. Mattingly II Henry W. Hartsfield, Jr.	7 : 1 : 9	Fourth flight of Space Shuttle, first DoD payload, additional scientific payloads. Returned 4 July. Completed orbital flight testing program. Returned for reuse.

U.S. and Soviet Manned Spaceflights 1961-1982

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz T-7	19 Aug. 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)	11 Nov. 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.

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant[a]	Thrust (kilo-newtons)	Max. Dia. x Height (m)	Max. Payload (kg)[b]: 185-Km Orbit	Max. Payload (kg)[b]: Geosynch.-Transfer Orbit	Max. Payload (kg)[b]: Circular Sun-Synch. Orbit	First Launch[c]
Scout	1. Algol IIIA	Solid	431.1	1.14 x 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 x 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 x 35.4	3 045	1275	2 135[d]	1982(60)
	9 TX 526-2	Solid	375 each		2 180[d]			
	2. Delta	N_2O_4/Aerozine-50	44.2					
	3. TE 364-4	Solid	65.8					
Atlas E/F-TE 364-4	1. Atlas booster & sustainer	LOX/RP-1	1 722.0	3.05 x 28.1	2 090[d f]	–	1 500[d]	1972(67)
	2. TE 364-4	Solid	65.8					
Atlas-Centaur	1. Atlas booster & sustainer	LOX/RP-1	1 913.0	3.05 x 39.8	5 680	2045	–	1962
	2. Centaur	LOX/LH_2	146.0					
					185-Km Orbit	Direct Geosynch. Orbit	Sun-Synch. Transfer Orbit	
Titan IIIB-Agena	1. LR-87	N_2O_4/Aerozine	2 341.0	3.05 x 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 IIIC	1. Two segment 3.05-m dia.	Solid	10 675.2	3.05 x 48.2	13 245	1610[d]	–	1965
	2. LR-87	N_2O_4/Aerozine	2 341.0					
	3. LR-91	N_2O_4/Aerozine	455.0					
	4. Transtage	N_2O_4/Aerozine	69.8					
Titan IIID	Same as Titan IIIC without Transtage			3.05 x 46.9	11 020[d]	–	9 750[d]	1971
Titan III(34)D	1. Two 5½-segment 3.05-m dia.	Solid	11 564.8	3.05 x 49.4	12 520[d]	–	11 340[d]	[g]
	2. LR-87	N_2O_4/Aerozine	2 366.3					
	3. LR-91	N_2O_4/Aerozine	449.3					
Titan III(34)D/IUS	Same as Titan III (34)D plus:			3.05 x 48.0	14 920	1850[d]	–	1982
	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 x 46.9	14 920	1855[d]	–	[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 x 37.24 wing long span	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 x 45.45				
	Mounted on external tank (ET)			8.40 x 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 $UDMH/N_2H_4 = N_2O4$/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] Initial operational capability in December 1981; launch to be scheduled as needed.

[h] Initial operational capability in December 1982; launch to be scheduled as needed.

[i] At sea level.

NOTE: Data should not be used for detailed NASA mission planning without concurrence of the director of expendable launch vehicles.

Space Activities of the U.S. Government

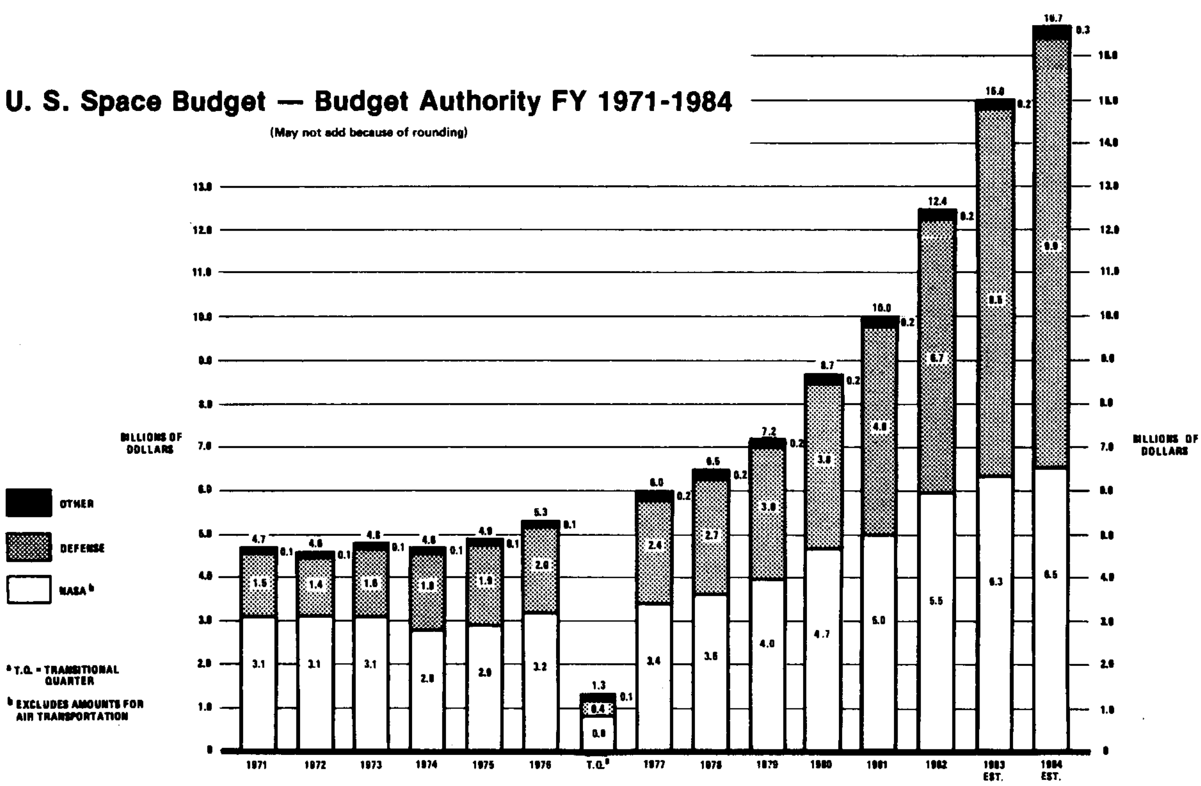
HISTORICAL BUDGET SUMMARY — BUDGET AUTHORITY

(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	1824.9	1796.8	1298.2	147.8	50.7	...	...	1.3	3 294.8
1963	3673.0	3626.0	1549.9	213.9	43.2	...	...	1.5	5 434.5
1964	5099.7	5016.3	1599.3	210.0	2.8	...	...	3.0	6 831.4
1965	5249.7	5137.6	1573.9	228.6	12.2	...	...	3.2	6 955.5
1966	5174.9	5064.5	1688.8	186.8	26.5	...	...	3.2	6 969.8
1967	4965.6	4830.2	1663.6	183.6	29.3	...	...	2.8	6 709.5
1968	4587.3	4430.0	1921.8	145.1	28.1	0.2	0.5	3.2	6 528.9
1969	3990.9	3822.0	2013.0	118.0	20.0	.2	.7	1.9	5 975.8
1970	3745.8	3547.0	1678.4	102.8	8.0	1.1	.8	2.4	5 340.5
1971	3311.2	3101.3	1512.3	94.8	27.4	1.9	.8	2.4	4 740.9
1972	3306.6	3071.0	1407.0	55.2	31.3	5.8	1.6	2.8	4 574.7
1973	3406.2	3093.2	1623.0	54.2	39.7	10.3	1.9	2.6	4 824.9
1974	3036.9	2758.5	1766.0	41.7	60.2	9.0	3.1	1.8	4 640.3
1975	3229.1	2915.3	1892.4	29.6	64.4	8.3	2.3	2.0	4 914.3
1976	3550.3	3225.4	1983.3	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	3817.8	3440.2	2411.9	21.7	90.8	9.5	6.3	2.4	5 982.8
1978	4060.1	3622.9	2738.3	34.4	102.8	9.7	7.7	2.4	6 518.2
1979	4595.5	4030.4	3035.6	58.6	98.4	9.9	8.2	2.4	7 243.5
1980	5240.2	4680.4	3848.4	39.6	92.6	11.7	13.7	2.4	8 688.8
1981	5518.4	4992.4	4827.7	40.5	87.0	12.3	15.5	2.4	9 977.8
1982	6043.9[b]	5527.6	6678.7	60.6	144.5	12.1	15.2	2.0	12 440.7
1983 est.	6830.9	6278.1	8490.9	61.9	185.6	9.5	21.0	1.0	15 048.0
1984 est.	7098.0	6508.6	9881.5	60.1	208.4	9.0	25.8	1.0	16 694.4

[a] Excludes amounts for air transportation (subfunction 402).
[b] Includes $33.5 million unobligated funds that lapsed.

SOURCE: Office of Management and Budget.



APPENDIX E-2

Space Activities Budget

(in millions of dollars by fiscal year)

Federal Space Programs	Budget Authority 1982 Actual	Budget Authority 1983 Est.	Budget Authority 1984 Est.	Outlays 1982 Actual	Outlays 1983 Est.	Outlays 1984 Est.
Federal agencies:						
NASA[a]	5 527.6	6 278.1	6 508.6	5 463.3	6 146.5	6 385.2
Defense	6 678.7	8 490.9	9 881.5	4 771.5	6 290.7	7 504.5
Energy	60.6	61.9	60.1	59.5	65.8	57.9
Commerce	144.5	185.6	208.4	142.4	185.2	208.4
Interior	12.1	9.5	9.0	12.1	9.9	9.1
NSF	2.0	1.0	1.0	2.2	1.5	1.2
Agriculture	15.2	21.0	25.8	15.2	21.0	25.8
Total	12 440.07	15 048.0	16 694.4	10 466.2	12 720.6	14 192.1
NASA:						
Space flight	3 601.3	4 109.1	4 049.0	3 543.3	4 033.8	4 027.6
Space science, applications, and technology	1 391.8	1 567.8	1 638.0	1 456.9	1 516.8	1 600.6
Air transportation	516.3	552.8	589.4	562.5	566.6	587.4
Supporting operations	544.1[b]	609.6	830.1	473.0	604.3	765.5
Less receipts	-9.6	-8.4	-8.5	-9.6	-8.4	-8.5
Total NASA	6 043.9	6 830.9	7 098.0	6 025.8	6 713.1	6 972.6

[a] Excludes amounts for air transportation.
[b] Includes $33.5 million unobligated funds that lapsed.

SOURCE: Office of Management and Budget.

APPENDIX E-3

Aeronautics Budget

(in millions of dollars by fiscal year)

Federal Aeronautics Programs	Budget Authority 1982 Actual	Budget Authority 1983 Est.	Budget Authority 1984 Est.	Outlays 1982 Actual	Outlays 1983 Est.	Outlays 1984 Est.
NASA[a]	516.3	552.8	589.4	562.5	566.6	587.4
Department of Defense[b]	2984.0	3664.1	4079.0	2657.0	3048.4	3507.4
Department of Transportation[c]	81.0	121.0	286.0	89.0	115.0	217.0
Total	3581.3	4337.9	4954.4	3308.5	3730.0	4311.8

[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.

United States Space Policy

The White House Fact Sheets, 4 July 1982

The President announced today a national space policy that will set the direction of U.S. efforts in space for the next decade. The policy is the result of an interagency review requested by the President in August 1981. The 10-month review included a comprehensive analysis of all segments of the national space program. The primary objective of the review was to provide a workable policy framework for an aggressive, farsighted space program that is consistent with the administration's national goals.

As a result, the President's directive reaffirms the national commitment to the exploration and use of space in support of our national well-being, and establishes the basic goals of United States space policy which are to:

- strengthen the security of the United States;
- maintain United States space leadership;
- obtain economic and scientific benefits through the exploitation of space;
- expand United States private-sector investment and involvement in civil space and space related activities;
- promote international cooperative activities in the national interest; and
- cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

The principles underlying the conduct of the United States space program, as outlined in the directive are:

—The United States is committed to the exploration and use of space by all nations for peaceful purposes and for the benefit of mankind. "Peaceful purposes" allow activities in pursuit of national security goals.

—The United States rejects any claims to sovereignty by any nation over space or over celestial bodies, or any portion thereof, and rejects any limitations on the fundamental right to acquire data from space.

—The United States considers the space systems of any nation to be national property with the right of passage through and operation in space without interference. Purposeful interference with space systems shall be viewed as an infringement upon sovereign rights.

—The United States encourages domestic commercial exploitation of space capabilities, technology, and systems for national economic benefit. These activities must be consistent with national security concerns, treaties, and international agreements.

—The United States will conduct international cooperative space-related activities that achieve scientific, political, economic, or national security benefits for the Nation.

—The United States space program will be comprised of two separate, distinct and strongly interacting programs—national security and civil. Close coordination, cooperation, and information exchange will be maintained among these programs to avoid unnecessary duplication.

—The United States Space Transportation System (STS) is the primary space launch system for both national security and civil government missions. STS capabilities and capacities shall be developed to meet appropriate national needs and shall be available to authorized users—domestic and foreign, commercial and governmental.

—The United States will pursue activities in space in support of its right of self-defense.

—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 weapons systems, should those measures be compatible with United States national security.

Space Transportation System

The directive states that the space shuttle is to be a major factor in the future evolution of United States space programs and that it will foster further cooperative roles between the national security and civil programs to ensure efficient and effective use of national resources. The Space Transportation System (STS) is composed of the space shuttle, associated upper stages, and related facilities. The directive establishes the following policies governing the development and operation of the Space Transportation System:

—The STS is a vital element of the United States space program and is the primary space launch system for both United States national security and civil government missions. The STS will be afforded the degree of survivability and security protection required for a critical national space resource. The first priority of the STS program is to make the system fully operational and cost-effective in providing routine access to space.

—The United States is fully committed to maintaining world leadership in space transportation with a STS capacity sufficient to meet appropriate national needs. The STS program requires sustained commitments by each affected department or agency. The United States will continue to develop the STS through the National Aeronautics and Space Administration (NASA) in cooperation with the Department of Defense (DoD). Enhancement of STS operational capability, upper stages, and methods of deploying and retrieving payloads should be pursued, as national requirements are defined.

—United States Government spacecraft should be designed to take advantage of the unique capabilities of the STS. the completion of transition to the shuttle should occur as expeditiously as practical.

—NASA will assure the shuttle's utility to the civil users. In coordination with NASA, the DoD will assure the shuttle's utility to national defense and integrate national security missions into the shuttle system. Launch priority will be provided for national security missions.

—Expendable launch vehicle operations shall be continued by the United States Government until the capabilities of the STS are sufficient to meet its needs and obligations. Unique national security considerations may dictate developing special-purpose launch capabilities.

—For the near term, the STS will continue to be managed and operated in an institutional arrangement consistent with the current NASA/DoD Memoranda of Understanding. Responsibility will remain in NASA for operational control of the STS for civil missions and in the DoD for operational control of the STS for national security missions. Mission management is the responsibility of the mission agency. As the STS operations mature, the flexibility to transition to a different institutional structure will be maintained.

—Major changes to STS program capabilities will require Presidential approval.

The Civil Space Program

In accordance with the provisions of the National Aeronautics and Space Act, the directive states that the civil space program shall be conducted:

- to expand knowledge of the Earth, its environment, the solar system, and the universe;
- to develop and promote selected civil applications of space technology;
- to preserve the United States leadership in critical aspects of space science, applications, and technology; and
- to further United States domestic and foreign policy objectives.

The directive states the following policies which shall govern the conduct of the civil space program:

—United States Government programs shall continue a balanced strategy of research, development, operations, and exploration for science, applications, and technology. The key objectives of these programs are to: (1) preserve the United States preeminence in critical space activities to enable continued exploitation and exploration of space; (2) conduct research and experimentation to expand understanding of: (a) astrophysical phenomena and the origin and evolution of the universe through long-lived astrophysical observation; (b) the Earth, its environment, its dynamic relation with the Sun; (c) the origin and evolution of the solar system through solar, planetary, and lunar sciences and exploration; and (d) the space environment and technology to advance knowledge in the biological sciences; (3) continue to explore the requirements, operational concepts, and technology associated with permanent space facilities; (4) conduct appropriate research and experimentation in advanced technology and systems to provide a basis for future civil applications.

—The United States Government will provide a climate conducive to expanded private-sector investment and involvement in space activities, with due regard to public safety and national security. These space activities will be authorized and supervised or regulated by the Government to the extent required by treaty and national security.

—The United States will continue cooperation with other nations in international space activities by conducting joint scientific and research programs, consistent with technology transfer policy, that yield sufficient benefits to the United States, and will support the public, nondiscriminatory, direct readout of data from Federal civil systems to foreign ground stations and the provision of data to foreign users under specified conditions.

—The Department of Commerce, as manager of Federal operational space remote sensing systems, will: (1) aggregate Federal needs for these systems to be met by either the private sector or the Federal Government; (2) identify needed research and development objectives for these systems; and (3) in coordination with other departments or agencies, provide regulation of private sector operation of these systems.

The National Security Space Program

The directive states that the United States will conduct those activities in space that it deems necessary to its national security. National security space programs shall support such functions as command and control, communications, navigation, environmental monitoring, warning, surveillance, and space defense. The directive states the following policies which shall govern the conduct of the national security program:

—Survivability and endurance of space systems, including all system elements, will be pursued commensurate with the planned use in crisis and conflict, with the threat, and with the availability of other assets to perform the mission. Deficiencies will be identified and eliminated, and an aggressive, long-term program will be undertaken to provide more assured survivability and endurance.

—The United States will proceed with development of an antisatellite (ASAT) capability, with operational deployment as a goal. The primary purposes of a United States ASAT capability are to deter threats to space systems of the United States and its allies and, within such limits imposed by international law, to deny any adversary the use of space-based systems that provide support to hostile military forces.

—The United States will develop and maintain an integrated attack warning, notification, verification, and contingency reaction capability which can effectively detect and react to threats to United States space systems.

—Security, including dissemination of data, shall be conducted in accordance with Executive orders and applicable directives for protection of national security information and commensurate with both the missions performed and the security measures necessary to protect related space activities.

Inter-Program Responsibilities

The directive contains the following guidance applicable to and binding upon the United States national security and civil space programs:

—The national security and civil space programs will be closely coordinated and will emphasize technology sharing within necessary security constraints. Technology transfer issues will be resolved within the framework of directives, Executive orders, and laws.

—Civil Earth-imaging from space will be permitted under controls when the requirements are justified and assessed in relation to civil benefits, national security, and foreign policy. These controls will be periodically reviewed to determine if the constraints should be revised.

—The United States Government will maintain and coordinate separate national security and civil operational space systems when differing needs of the programs dictate.

Policy Implementation

The directive states that normal interagency coordinating mechanisms will be employed to the maximum extent possible to implement the policies enunciated. A Senior Interagency Group (SIG) on Space is established by the directive to provide a forum to all Federal agencies for their policy views, to review and advise on proposed changes to national space policy, and to provide for orderly and rapid referral of space policy issues to the President for decisions as necessary. The SIG (Space) will be chaired by the Assistant to the President for National Security Affairs and will include the Deputy Secretary of Defense, Deputy Secretary of State, Deputy Secretary of Commerce, Director of Central Intelligence, Chairman of the Joint Chiefs of Staff, Director of the Arms Control and Disarmament Agency, and the Administrator of the National Aeronautics and Space Administration. Representatives of the Office of Management and Budget and the Office of Science and Technology Policy will be included as observers. Other agencies or departments will participate based on the subjects to be addressed.

Background

In August 1981, the President directed a National Security Council review of space policy. The direction indicated that the President's Science Adviser, Dr. George Keyworth, in coordination with other affected agencies, should examine whether new directions in national space policy were warranted. An interagency working group was formed to conduct the study effort and Dr. Victor H. Reis, an Assistant Director of the Office of Science and Technology Policy was designated as Chairman. The group addressed the following fundamental issues: (1) launch vehicle needs; (2) adequacy of existing space policy to ensure continued satisfaction of United States civil and national security program needs; (3) shuttle organizational responsibilities and capabilities; and, (4) potential legislation for space policy. The reports on the various issues formed the basis of the policy decisions outlined here.

The following agencies and departments participated: State, Defense, Commerce, Director of Central Intelligence, Joint Chiefs of Staff, Arms Control and Disarmament Agency, and the National Aeronautics and Space Administration, as well as the National Security Council staff and the Office of Management and Budget.

Aeronautical Research and Technology Policy

Office of Science and Technology Policy, November 1982

I. INTRODUCTION

Since 1915, the U.S. government has provided national leadership and significant financial support for the development of aeronautical research and technology (R&T). Approximately one-third of the U.S. defense budget is spent on aeronautical products and their support, and commercial aircraft sales contribute the largest positive balance of trade among U.S. manufactured goods. Superior aeronautical R&T has been essential to the current U.S. preeminence in both military and civil aviation. Given the ever-increasing Soviet military pressures and foreign commercial aviation competition, future preeminence depends on effective U.S. R&T programs. Significant questions have been raised concerning the appropriateness and effectiveness of current U.S. aeronautical R&T policies, and the U.S. government's role in support of aeronautical R&T.

In response to these questions, the Office of Science and Technology Policy (OSTP), in the Executive Office of the President, chaired a multi-agency study group that reviewed national aeronautical R&T policy. The following central issues and/or questions were addressed:

- Is aeronautics a mature technology and is continued investment justified by potential benefits?
- What are the proper government roles in aeronautical R&T and does the present institutional framework satisfy these roles or should it be changed?

The study was conducted from February 1982 through August 1982 by an interagency working group and a senior-level steering group consisting of individuals from: OSTP (chair), the Office of Management and Budget (OMB), Council of Economic Advisors (CEA), Department of Defense (DOD), National Aeronautics and Space Administration (NASA), Department of Transportation [Federal Aviation Administration (FAA)], and Department of Commerce (DOC). Two observers, one from industry and one from the university community, also participated. Further data were acquired from an extensive questionnaire sent to aeronautical industry leaders and from interviews with their representatives. While considering the broad range of aeronautics and aeronautical R&T, the study group concentrated on the air vehicle and only peripherally addressed external weapon systems and air traffic control systems. The study group reviewed past and current government policies on aeronautical research, and extensively addressed current and future needs, capabilities, and incentives for such research in both government and private industry. Analysis of policy options and alternatives resulted in specific findings and recommendations. This summary report, Volume I, provides the study findings and recommendations in brief, and a summary of the major rationale that led to these results. Volume II provides analyses and data to support the results. Volume I was fully reviewed and approved by all agencies represented on the Steering Group (OSTP, OMB, CEA, DOD, NASA, FAA, DOC) and further reviewed and approved by the National Security Council (NSC) and the Office of the U.S. Trade Representatives (USTR). Volume II was reviewed and approved by members and agency support staff on the working group. This study was accomplished to aid senior Administration officials in establishing and implementing policies affecting aeronautical R&T.

Victor Reis	Louis Montulli
Steering Group Chairman	Working Group Chairman

III. FINDINGS AND RECOMMENDATIONS

This chapter presents the study group's findings and principal recommendations.

Findings

The study group presented the following findings:

1. *Importance of Aeronautics*

- The United States depends heavily on technical superiority of military aircraft for national defense—approximately one-third of the DOD budget is for procurement, maintenance, and operation of aeronautical systems.
- Civil aircraft are the dominant common carrier mode of inter-city travel in the United States. The U.S. government is responsible for air traffic control and safety.

2. *Nature of Aeronautics Industry*

- A healthy, competitive civil aeronautics manufacturing industry reduces the cost of providing an essential military industrial base and wartime mobilization surge capacity.
- A successful aeronautics industry requires a continuous input of multidisciplined advanced technologies from both inside and outside the aeronautical industry.
- The capital investment required to develop a new aircraft often exceeds the net worth of the sponsoring company.

Section I, Introduction, and III, Findings and Recommendations, from volume 1, *Summary Report,* of OSTP report *Aeronautical Research and Technology Policy,* November 1982.

- Antitrust laws have constrained U.S. companies from domestic joint ventures but have often allowed international joint ventures. However, industry has not yet attempted to take full advantage of recent relaxation of some antitrust constraints.
- Aeronautics industry prosperity is influenced by worldwide economic conditions, foreign trade policies, and government policies, as well as R&T.

3. *Aeronautical R&T*

- Large gains are expected from continued aeronautical R&T.
- Continued strong advancement in aeronautical R&T is essential for national security and for continued success of the U.S. civil aeronautics industry.
- The aeronautical R&T development activities in support of future military and civil applications are largely common, thereby compounding the value of the resulting research.
- Industry-funded aeronautical R&T is predominantly near-term focused. Private companies have been generally unable to effectively capture the benefits of internally funded aeronautical R&T development. As a result, a market disincentive exists for such R&T activities.

Recommendations

The study group made the following recommendations:

1. *National Goals in Aeronautics and Aeronautical R&T*

Recognizing aviation's unique role in national defense and its significance in the U.S. transportation system, the study group recommends the following goals for industry and government:

- *In Aeronautics*
  - Maintain a superior military aeronautical capability.
  - Provide for the safe and efficient use of the national airspace system, vehicles operated within the system, and facilities required for those operations.
  - Maintain an environment in which civil aviation services and manufacturing can flourish.
  - Ensure that the U.S. aeronautical industry has access to and is able to compete fairly in domestic and international markets, consistent with U.S. export policy.
- *In Aeronautical R&T*
  - Ensure the timely provision of a proven technology base to support future development of superior U.S. aircraft.
  - Ensure the timely provision of a proven technology base for a safe, efficient, and environmentally compatible air transportation system.

2. *U.S. Government Role*

After considering alternative policies consistent with national needs, objectives, and the U.S. economic system, the study group recommends:

- Government support for aeronautical R&T development and for military aeronautical technology demonstration, consistent with overall government priorities and the availability of funds.

3. *Government Agency Roles*

The study group recommends that the government maintain the present institutional framework in which

- DOD funds, directs, and implements aeronautical technology development and demonstration programs directed specifically toward military applications.
- NASA funds, directs, and implements aeronautical R&T development programs and supports military aeronautical technology demonstration programs.
- NASA and DOD encourage transfer of aeronautical research results to and within U.S. industry.
- Both DOD and NASA manage, maintain, and operate aeronautical research, development, test, and evaluation facilities.
- The FAA, with NASA and DOD support, is responsible for air traffic control and safety-related aeronautical R&T.

The study group found the general coordination of NASA and DOD programs to be both frequent and highly professional. However, since the creation of NASA in 1958 and the elimination of the NACA Advisory Board, senior aeronautical policy coordination between NASA, DOD, and industry has been weakened. The panel recommends

- The reinstitution of a high-level NASA, DOD, and industry committee, which would meet at least once a year to review and coordinate all aeronautical R&T policies.

4. *Facilities*

The study group examined the capabilities and limitations of the existing and developing aeronautical facilities and concluded that present and planned major facilities are adequate. However, continued maintenance and modernization will be required. Specifically, improvements to and expansion of computational capability should be considered.

Disparity in approach to user charges between DOD and NASA facilities creates a significant potential for inappropriate program distribution and use of some facilities. It is recommended that

- NASA and DOD develop a common framework of appropriate incentives and proper joint management coordinating mechanisms to ensure that the use of NASA and DOD aeronautical facilities is consistent with government priorities and the needs of the user programs.

5. *Technology Transfer*

The study group viewed the rapid, uncontrolled dissemination of unclassified aeronautical R&T data by the United States to foreign parties as detrimental to U.S. preeminence in military and civil aviation. The group further determined that significant, high-quality aeronautical R&T is being accomplished by many developed countries. The United States is not now fully collecting and utilizing this available, unclassified foreign technology. After a study of technology transfer, including a review by DOD and other agencies, the study group recommends that

- NASA and DOD, in conjunction with other U.S. government and non-government agencies, review the procedures for disseminating aeronautical R&T documents.
- NASA provide a plan for a centralized means of collecting unclassified aeronautical R&T documents, conference proceedings, and meeting results.

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