Aeronautics and Space Report of the President

Fiscal Year 1992 Activities

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Fiscal Year 1992 Activities

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National Aeronautics
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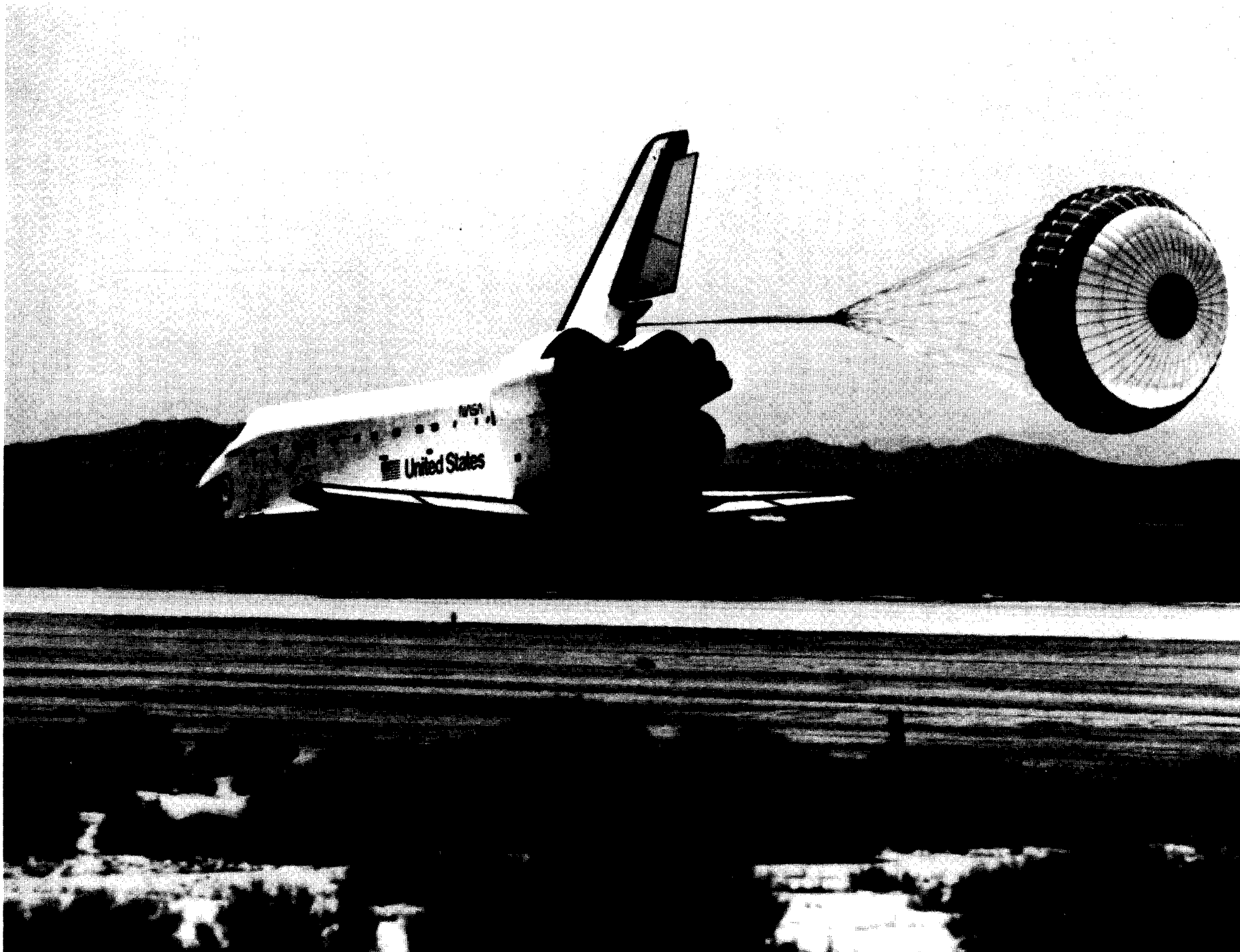

Space Shuttle Endeavour making its first landing after a successful nine-day mission in Earth orbit.

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Other Aeronautical and Space Activities

Executive Summary

Note: The National Aeronautics and Space Act of 1958 directed that the annual Aeronautics and Space Report include a "comprehensive description of the programmed activities and the accomplishments of all agencies of the United States in the field of aeronautics and space activities during the preceding calendar year." This year's report (like last year's) has been prepared on a fiscal year basis, which is consistent with the budgetary period now used in programs of the Federal Government. The Administration is working with Congress to amend the National Aeronautics and Space Act of 1958 accordingly.

Fiscal Year (FY) 1992 was a significant one for U.S. aeronautics and space efforts. It included seven Space Shuttle missions and 14 Government launches of Expendable Launch Vehicles (ELVs) carrying a variety of payloads ranging from NASA missions to classified payloads. In addition, there were eight launches of ELVs by commercial launch service providers operating under licenses issued by the Department of Transportation's Office of Commercial Space Transportation. On December 7, 1991, the Air Force achieved initial launch capability for the new Atlas II launch vehicle in a commercial launch by General Dynamics with support from the Air Force. The other ELV missions launched four Navstar Global Positioning System, two Defense Satellite Communications System, and one Defense Meteorological Satellite Program satellites as well as two classified payloads and four NASA spacecraft. The Shuttle missions included one using the Atmospheric Laboratory for Applications and Science (ATLAS-1) to study the Sun and our atmosphere as well as the first flight of the newest orbiter, Endeavour, which rendezvoused with, retrieved, and replaced the perigee kick motor of the INTELSAT VI (F-3) satellite that the International Telecommunications Satellite Organization (INTELSAT) controllers then deployed into its intended orbit. In aeronautics, efforts have ranged from development of new civil and military aircraft and technologies to research and development of ways to reduce aircraft noise and improve flight safety and security. A key environmental effort in FY 1992 was monitoring ozone depletion. One of the major Earth science highlights of the year was finding that, like the ozone layer over the Antarctic regions with its well-documented annual depletion, the ozone layer in the Northern Hemisphere is increasingly vulnerable to depletion by synthetic chemicals. Several Federal agencies have cooperated to study this and other environmental problems so we can improve the prospects for future generations, who will inhabit the Earth. In these and many other ways discussed below, the budgets for aeronautics and space—distributed among 14 different Federal agencies—have promoted important advances in the Nation's scientific and technical knowledge, promising to enhance the quality of life on Earth through improved scientific understanding, provide a more viable economy and healthier environment, and ensure we live in a safer world.

National Aeronautics and Space Administration (NASA)

In a variety of areas during FY 1992, NASA advanced the Nation's aeronautical and space goals. FY 1992 proved, for example, to be a year of significant findings in the area of space science, highlighted by the results from NASA's Cosmic Background Explorer (COBE). In what may be one of the discoveries of the decade, the COBE team of scientists announced in April 1992 the discovery of the largest and oldest objects ever detected in the universe, showing for the first time that the big bang was not perfectly smooth and uniform. In another area of astronomy, the Compton Gamma Ray Observatory (GRO) has found that a number of quasars, previously known as intense emitters of optical and radio radiation, also exhibit intense emission of very high energy gamma rays.

Launched on June 7, 1992, the Extreme Ultraviolet Explorer (EUVE) was opening the virtually unexplored window in the electromagnetic spectrum, the extreme ultraviolet. The first spacecraft in a new series of Small Explorers, the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX), launched on July 3, 1992, is designed to investigate anomalous cosmic rays and other phenomena of space physics. Yohkoh, a joint mission between NASA and Japan's Institute for Space and Astronautical Science (ISAS), has been providing insights into the physics of solar flares, including their topology, energetics, and timing. The Geotail satellite, launched on July 24, 1992, is the first mission in the International Solar-Terrestrial Physics initiative, an effort to derive the physics of the behavior of the solar-terrestrial system so as to predict how the Earth's atmosphere will respond to changes in the solar wind.

In planetary astronomy, Mars Observer (MO), a spacecraft that will enter a near-polar orbit around Mars in August 1993, successfully launched from Cape Canaveral Air Force Station, FL, on September 25, 1992. Also, by the end of September, Magellan had successfully mapped over 99 percent of the Venus's surface.

In space flight and space technology the Space Shuttle Main Engine (SSME) program continued its aggressive test activity. The Advanced Solid Rocket Motor (ASRM) program made significant progress in facility construction and motor design. During 1992, the strategic planning process for use of Space Station Freedom (SSF) began. Two Shuttle missions this year successfully tested Space Station equipment and operations concepts. The United States Microgravity Laboratory (USML-1), launched June 25, 1992, was the first Spacelab flight dedicated solely to microgravity research. This flight served as a "dress rehearsal" for Space Station Freedom, and the knowledge gained from the investigations will assist NASA in preparing for work on Freedom later in the 1990s. Other life sciences-related missions included the 8-day International Microgravity Laboratory (IML-1) mission launched on January 22, 1992, and Spacelab J (SL-J), launched on September 12, 1992, a reimbursable mission with Japan.

With respect to the environment on Earth, results from the second Airborne Arctic Stratospheric Expedition (AASE-II), a 6-month study of the atmosphere using NASA research aircraft, correlated with observations from the Upper Atmosphere Research Satellite (UARS), contributed to increased understanding of the degree and nature of ozone depletion in the Northern and mid-latitudes. Measurements from NASA's Total Ozone Mapping Spectrometer revealed that ozone levels over the Antarctic regions once again reached record lows in October 1991. A major step in understanding the oceans came on August 10, 1992, when the U.S. and France successfully launched the joint Ocean Topography Experiment, TOPEX/POSEIDON.

NASA's Space Network continued to provide tracking and communications services to a variety of Earth-orbital missions. Using its Tracking and Data Relay Satellite System (TDRSS) Space Network—a space-based system providing communications plus command and control services to low Earth-orbiting spacecraft—during FY 1992 the network provided communications services to three new customers: the Upper Atmosphere Research Satellite, launched September 12, 1991; Extreme Ultraviolet Explorer, launched June 7, 1992; and TOPEX/POSEIDON. The growth in TDRS-compatible, low Earth-orbiting satellites requiring TDRS services resulted in a 38 percent increase in minutes of service provided in FY 1992 over FY 1991.

Also in 1992, among other activities, NASA's Office of Space Communications redesignated the Packet Data Processor facility, initially designed to meet the unique requirements of the Gamma Ray Observatory (GRO), as a multi-satellite facility to enable the processing of scientific data received from NASA's next generation of Earth-orbiting spacecraft. The Office of Space Communications evolved a new Transportable Payload Operations Control Center architecture, which used high power workstations instead of large central computers to provide service faster, better, and more cheaply. And during FY 1992, NASA's Ground Network facilities also provided communication services during the launch, flight, and recovery of high-altitude balloons and rockets employed for research in such scientific disciplines as geophysics, astrophysics, and astronomy. These facilities provided spacecraft communications as well to the Space Shuttle; to planetary spacecraft; and to Earth-orbiting spacecraft performing a variety of Earth observing missions.

In the aeronautical arena, the Integrated High Performance Turbine Engine Technology (IHPTET) initiative was a coordinated DoD/NASA/industry effort to double turbopropulsion capability and reduce cost for military aircraft engines with no compromises in propulsion system life, reliability, and maintainability. NASA's Subsonic Aircraft Research during FY 1992 focused on developing selected new technologies to ensure the competitiveness of U.S. subsonic aircraft in the world market and enhance the safety and productivity of the Nation's airspace. Much of NASA's research focused on reducing drag and improving lift.

NASA was also engaged in high-speed research, focused on resolving critical environmental issues and laying the technological foundation for an economical, next-generation supersonic transport expected to be critical to the competitive posture of the American aerospace industry in the next century. During 1992, NASA's testing and modeling showed that it would be possible to lower emissions and noise levels for such an aircraft to within program goals. Among other aeronautics programs, NASA's Hypersonic Research program supported fundamental research into the physical processes of flight at hypersonic speeds; it is also developing new, innovative technologies that will allow future air-breathing, hypersonic vehicles to operate safely in the hypersonic environment. NASA's Critical Disciplines Research during FY 1992 focused on pioneering the development of innovative concepts and providing physical understanding and theoretical, experimental, and computational tools required for efficient design and operation of advanced aerospace vehicles.

As part of its program to encourage private sector involvement and investment in new, high-technology, space-related products and services, in November 1991, NASA's Office of Commercial Programs (OCP) established two new Centers for the Commercial Development of Space (CCDS) to specialize in advanced satellite communications and other space-based telecommunications technologies. These two new centers brought the total number in the CCDS program to 17 at the end of the fiscal year. While most CCDS technologies were still in the experimental phase at the end of FY 1992, there had already been significant results in materials processing and biotechnology. In another area, OCP has co-funded 12 projects with industry in the second round of the Earth Observation Commercial Application Program, which promotes the development of new or improved products and services in the area of remote sensing. In the area of technology transfer, Regional Technology Transfer Centers (RTTCs), established in six regions spanning the U.S., began operating in January 1992. To give but one example of results in this area, NASA's Stennis Space Center and the Wilmer Eye Institute at the Johns Hopkins Medical Institution have developed a Low Vision Enhancement System to aid the vision impaired.

Department of Defense (DoD)

For the DoD in FY 1992, the Air Force launched four Delta IIs carrying Navstar Global Positioning System (GPS) satellites. The Air Force successfully launched two Defense Satellite Communications System (DSCS) satellites with the Atlas II, and there was a single Atlas E launch on November 28, 1991, supporting a Defense Meteorological Satellite Program satellite. The Air Force also launched a Titan IV with a classified DoD payload on November 7, 1991, and on April 25, 1992, it launched a Titan II booster, likewise carrying a classified DoD payload, from Vandenberg AFB. Additionally, on November 24-25, 1991, the crew of Space Shuttle Atlantis (STS-44) and an Inertial Upper Stage successfully launched an enhanced Defense Support Program (DSP) satellite, the third in the "DSP-I" block of satellites.

The Taurus standard small launch vehicle capitalized on the Defense Advanced Research Project Agency's (DARPA's) previous investment in the Pegasus air-launched vehicle to produce a ground-launched rocket with greater payload capacity. The rocket passed a major milestone this year with the successful integration and testing of the full-scale engineering vehicle. In satellite technology, the existing mix of 4 developmental and 15 operational GPS satellites at the end of the year provided worldwide, two-dimensional, navigational coverage 24 hours a day and worldwide, three-dimensional coverage at least 21 hours a day. In 1992, the Air Force also had several modernization projects underway to sustain and improve DSP's warning and surveillance capabilities.

The DSCS continued to serve as the long-haul, high capacity communications system supporting the worldwide command and control of the U.S. Armed Forces and other Government agencies. The DSCS program successfully launched two new DSCS III satellites on February 10 and July 2, 1992. These launches marked the start of a replenishment program for the DSCS constellation. Still in development was Milstar, programmed to be the cornerstone of the DoD's Military Satellite Communications architecture in the future. The first Milstar satellite was on track at the end of the fiscal year for delivery in December 1992, with satellites 2 and 3 at 90 and 60 percent completion, respectively. Meanwhile, the Fleet Satellite Communications System (FLTSATCOM) provided worldwide Navy and DoD Ultra High Frequency (UHF) satellite communications through a constellation of four Navy-owned FLTSAT and three leased satellites positioned in geosynchronous orbit at four locations around the Earth.

The Strategic Defense Initiative Organization engaged during FY 1992 in a wide-ranging research program. It continued work, for example, on the development of miniaturized and accurate subsystems for interceptors. The Defense Nuclear Agency (DNA) continued in FY 1992 to develop technology allowing space systems' survivability in hostile environments.

In the field of aeronautics, the DoD's Pilot's Associate Program applied many of the technologies being developed under the Strategic Computing Program of DARPA and the U.S. Air Force to assist pilots in making decisions in potential combat situations. The program culminated in FY 1992 with a successful demonstration in an advanced flight simulator representative of the fighter aircraft projected for the mid-1990s. Another important research and development effort involved the National Aero-Space Plane (NASP), a Presidentially-directed, joint DoD-NASA program. Its objective was to develop and validate technologies for an entirely new generation of aerospace vehicles, some of which will be single-stage-to-orbit space planes that fly at hypersonic speeds to provide flexible, efficient space-launch capability with horizontal takeoffs and landings on runways. Another capability will be a long-range hypersonic cruise within the atmosphere. The NASP program has fabricated component hardware, manufactured materials, and performed aerodynamic, mechanical, and thermal ground tests.

In another development program, the X-31A Enhanced Fighter has demonstrated increased maximum turn rates and a decreased turning radius, resulting in an ability to point its nose rapidly. FY 1992 achievements included a post-stall flight to 50 degrees Angle of Attack (AOA) on November 19, 1991; a post-stall flight to 70 degrees AOA; and a full-stick velocity vector roll to the same AOA, both on September 18, 1992. Throughout the envelope, the aircraft exhibited pilot-friendly handling. Other programs to develop or upgrade aircraft for the DoD—the FA-18E/F, the B-2, the AX (a multi-mission aircraft to replace current medium/long-range strike-interdiction aircraft in the Navy and Air Force), the X-29 Advanced Technology Demonstrator, and the Advanced Fighter Technology Integration program—all made notable progress during FY 1992 as well.

In another area of the DoD's responsibilities, the Defense Meteorological Satellite Program provided timely, high quality, worldwide, visible and infrared cloud imagery and other specialized environmental data to support strategic missions. To meet the ongoing needs of the system's users, the first of the improved Block 5D-2 satellites launched on an Atlas E on November 28, 1991, from Vandenberg AFB, CA. In a related area, the Geodetic/Geophysical Follow-on (GFO) satellite program, the Navy awarded a contract that will lead to the launch of an operational radar altimeter satellite in support of tactical oceanography. The contract provides for the first satellite to be launched in late 1995.

Department of Commerce (DoC)

The DoC and its components continued to perform a variety of aeronautics and space-related activities. For example, astronomers at the National Institute of Standards and Technology (NIST) used data from the Hubble Space Telescope (HST) to determine that there were 15 parts of deuterium per million parts of ordinary hydrogen in interstellar gas, an amount suggesting less matter in the universe than many scientists believed. This indicates that the universe could continue expanding forever, as it has been doing since the beginning, according to the big bang theory. In other areas of astronomy, NIST scientists completed model studies of gravitational wave emissions during the slow in-spiral of compact stars to massive black holes that are hypothesized to be the nuclei of galaxies. The results suggest that such sources may be observable from an orbiting gravitational wave observatory.

To improve current propulsion systems and achieve the performance demands of future propulsion system designs, NIST engineers were characterizing new materials that reduce friction and wear. NIST scientists have also constructed the first stage of a vibration isolation system for the National Science Foundation (NSF)-sponsored Laser Interferometric Gravitational Observatory complex.

In atmospheric studies, NIST and the National Oceanic and Atmospheric Administration (NOAA) were collaborating on measurements of concentrations of various chemicals and compounds. Scientists were compiling data from these and other measurements into database tables that will enable atmospheric modelers to predict equilibrium conditions for the atmosphere and its chlorine pollutants. Relatedly, NIST scientists sought in a separate project to identify regional and global sources of important "greenhouse" gases—carbon monoxide, ozone, carbon and sulfur aerosols, and others that affected the quality of the atmosphere and the climate. Meanwhile, the NOAA series of satellites continued to provide data on ozone depletion and the weather. NOAA scientists were in the process of analyzing the data set for the time histories of globally-distributed total ozone amounts and of the annual depletion of ozone over Antarctica. During 1992, scientists within NOAA were also in the process of combining satellite-derived information with climatic data observed from the surface of the Earth to better understand the influence of urbanization on long-term temperature records. And National Environmental Satellite Data and Information Service (NESDIS) scientists plus the associated cooperative institutes were engaged in a variety of studies of severe storms.

In June, the DoC's Office of Space Commerce and NASA briefed industry on the potential role of commercial ventures in the Space Exploration Initiative (SEI), President Bush's challenge to establish a permanent outpost on the Moon and explore Mars. The President designated the DoC as the lead agency for encouraging private sector activities in support of SEI objectives.

Also, following the June Summit Meeting between President Bush and President Yeltsin of Russia, the DoC conducted a space technology assessment mission to Russia in July. The purpose of the trip was to allow technical representatives of U.S. industry to gain first-hand knowledge of the capabilities of Russian space industry before engaging in commercial discussions. The mission provided an unprecedented level of access to Russian space facilities and represented a new level of openness by Russia toward commercial cooperation with U.S. industry. In these and other ways, DoC contributed to the U.S. aeronautics and space goals.

Department of Energy (DoE)

The DoE continued the restart of its program to build Radioisotope Thermoelectric Generators (RTGs) to convert heat from Plutonium-238 into electric power. For example, in FY 1992, the Modular Radioisotope Thermoelectric Generator (MOD-RTG) program focused on the design, development, manufacture, and test of improved multicouples both in an electrically-heated engineering, 8-multicouple test module configuration and in individual multicouple test stations. The MOD-RTG design with its capability to tailor power to meet specific mission requirements should provide a significant advance in RTG specific power (watts/kilogram) and in improved efficiency for use in NASA's lunar, Martian, and solar system exploration as well as in DoD missions during the next decade. The DoE also continued its work on the SP-100 Space Reactor Program, which sought the development of a power system for civil and defense missions using a nuclear reactor capable of providing electric power in the range of tens to hundreds of kilowatts. Progress has also been made on technology for the separate thermionic space reactor.

In response to the Space Exploration Initiative (SEI) announced in 1989, DoE in cooperation with NASA has begun to develop Nuclear Propulsion, which promises to reduce costs, decrease the size of spacecraft, and provide shorter piloted Mars planetary missions. In addition to U.S. concepts, evaluation has begun of Russian fuel forms and testing capabilities.

Department of the Interior (DoI)

The DoI engaged in multiple applications of remote sensing from satellites and aircraft. For example, in 1992 the U.S. Geological Survey acquired over 237,000 square kilometers of additional Side-Looking Airborne Radar (SLAR) coverage for geologic, hydrologic, cartographic, and engineering applications in AL, MS, GA, FL, KS, CO, and UT. The Bureau of Reclamation continued numerous applications of remote sensing to a variety of resource management objectives including mapping irrigated lands in the Upper Colorado River basin from high altitude, color-infrared aerial photographs. The Bureau of Indian Affairs continued to conduct resource inventory and assessment projects to support its Indian Integrated Resource Information Program. Landsat Thematic Mapper data served, for example, to classify land cover, with emphasis on modeling fire fuels potential on the Jicarilla Indian Reservation, NM, and for woodlands mapping on reservations throughout southern SD.

The Bureau of Land Management obtained both satellite data and aerial photographs to aid in public land management. The National Park Service continued its extensive work developing vegetation community types from Landsat Thematic Mapper data in the Alaskan national parks. The U.S. Bureau of Mines has assembled a multidisciplinary team to study the utility of remote sensing for characterizing and inventorying mine waste as part of its Hazardous Waste Program. And, to give one other example, the Minerals Management Service was using the Global Positioning System (GPS) as a surveying and mapping tool in a pilot project to locate and position low water features accurately in the Gulf of Alaska to support offshore natural resource management activities.

In a very different area, using radar images from Magellan, the U.S. Geological Survey, under charter from NASA, has begun to provide maps that support scientific studies of the geological properties of Venus. Also during 1992, the U.S. Geological Survey completed topographic mapping of Mars at four different scales, using previously acquired Viking Orbiter images.

U.S. Department of Agriculture (USDA)

The USDA had a plethora of uses for remote sensing from either satellites or aircraft for agricultural assessment and resource management in such areas as insect infestations, drought, fires, vegetation changes, wildlife applications, crop assessment, and foreign market supply. A broad-based research program, using information from aircraft and satellites—especially Landsat, of whose data the Department was the largest user outside the DoD—continued to provide essential information on procedures for operational applications.

Federal Communications Commission (FCC)

In December 1991, the FCC approved the first commercial use of the C-band satellites leased by Columbia Communications from NASA on the TDRSS satellites located at 41 and 174 degrees West Longitude. The Commission has also authorized three companies to experiment with small, low Earth-orbiting satellites for communications purposes. On July 20, 1992, the FCC authorized Afrispace, Inc., an experimental license for the construction, launch, and operation of a geostationary satellite that will provide Broadcasting Satellite Sound services to Africa and the Middle East. Then on August 5, 1992, the FCC authorized four companies to conduct experiments involving low Earth orbiting satellites operating above the frequency of 1 gigahertz.

FY 1992 featured several important international meetings and conferences, including notably the 1992 International Telecommunication Union's (ITU's) World Administrative Radio Conference (WARC), which met from February 3 to March 3, 1992, at Torremolinos, Spain. The FCC spoke on behalf of the United States on issues from 1 to 3 gigahertz. The conferees reached agreements on most issues as a result of compromises following strenuous negotiations. Generally, the United States was able to secure worldwide frequency allocations that will enable its low Earth orbiting satellites to be employed in providing global telecommunication services including paging, data transfer, and voice broadcasting. To assist in implementing these services the FCC completed a negotiated rulemaking on low Earth-orbiting satellites below 1 gigahertz in August 1992. WARC also made several primary and secondary allocations for the Mobile Satellite Service, some worldwide and some regional, in frequencies between 1 and 3 gigahertz.

With respect to flight safety, in August 1992 the FCC amended Part 87 of its rules to establish technical standards and licensing procedures for Aircraft Earth Stations. The stations provided communications in support of domestic and international air traffic, including air traffic control and safety-related communications.

In other areas of FCC purview, an Ariane 44L launch vehicle successfully launched the INTELSAT VI (F-1) satellite, its fifth and last VI-series spacecraft, on October 29, 1991, from Kourou, French Guiana. Then, following its repositioning in May 1992, INTELSAT VI (F-3) became the fifth VI-series spacecraft in the INTELSAT network. The following month—on June 9, 1992—INTELSAT's highest powered satellite to date, the INTELSAT-K, was launched on an Atlas IIA from Cape Canaveral, FL. It brought to 19 the total number of satellites being operated by INTELSAT.

Meanwhile, on December 16, 1991, the INMARSAT-2 (F-3) satellite—the third of the International Maritime Satellite Organization's new generation of global, commercial, mobile communications satellites—was launched aboard an Ariane 4 rocket from Kourou, French Guiana. An Ariane 4 rocket also launched the fourth and final

INMARSAT-2 satellite (F-4) from Kourou on April 15, 1992. It completed the organization's second generation of satellites.

In addition, the FCC authorized a satellite system to operate in the previously unused 20/30 gigahertz frequency bands (Ka-band). This system, licensed to Norris Satellite Communications, Inc., will provide a variety of fixed-satellite services to users throughout the United States. In the established 4/6 gigahertz (C-band) and 12/14 gigahertz (Ku-band) frequency bands, there were three new domestic, fixed communications satellites launched for the United States during FY 1992. All of them were commercial replacement satellites launched into locations of satellites nearing the ends of their fuel lives. These launches raised to 33 the total number of domestic fixed satellites in orbit between 69 degrees West Longitude and 139 degrees West Longitude on the geostationary orbital arc.

Department of Transportation (DoT)

Federal Aviation Administration (FAA)

The FAA continued a growing research and development program to support its mission of ensuring civil aviation safety and efficiency. Under its ongoing Capital Investment Plan, the agency made progress on its Advanced Automation System, which will include new computer software, processors, tower position consoles, and workstations for air traffic controllers. At the same time, the Terminal Air Traffic Control Automation program worked to optimize terminal traffic flow by incorporating proven automation technology into the system. For example, the Controller Automation Spacing Aid project sought to use recently developed techniques in new applications to improve throughput of aircraft to the runway. The agency also pursued development of the Terminal Area Surveillance System to enhance air traffic control within terminal areas into the early 21st century.

The FAA worked with NASA on the Center-Terminal Radar Approach Control (TRACON) Automation System (CTAS), designed to increase safety while reducing delays, permitting more fuel-efficient aircraft descents, and decreasing controller workload. Under its Airport Surface Traffic Automation Program, the FAA sought to develop techniques to prevent runway incursions and more fully automate ground movement, thereby speeding traffic flow and increasing all-weather airport surface capacity. Research efforts to improve airport runways included preparing a preliminary design for a national airport pavement dynamic test facility. As the U.S. Navstar Global Positioning System neared full operational status, the FAA cooperated with NASA and international organizations to ensure that the benefits of satellite technology will be fully applied to civil aviation.

Progress also continued on three efforts the FAA began with other agencies to improve aviation weather services—the Aviation Gridded Forecast System, the Aviation Weather Product Generator, and the Integrated Terminal Weather System. The FAA continued development of the Terminal Doppler Weather Radar, which provides timely detection of hazardous wind shear in and near airport terminal approach and departure corridors. The agency's actions to combat the hazard of icing included investigations of deicing fluids and aircraft surface ice detection technologies. The FAA continued deployment of the airborne Traffic Alert and Collision Avoidance System (TCAS) and implementation of a transitional program to monitor the performance of TCAS II systems. Among many other safety-related programs were aircraft crashworthiness tests, aging aircraft research, and airport bird hazard studies.

In the area of civil aviation security, the FAA was engaged in a number of efforts to comply with the Aviation Security Improvement Act passed by Congress in November 1990. For instance, the agency pursued an extensive research and development effort to improve security through the use of explosives' detectors, x-ray technologies, and vapor/particle detection devices. The FAA also continued research into realizing the full civil potential of rotorcraft and tiltrotors. Among its projects to deal with environmental issues, the agency developed a computer tool known as Integrated Noise Model (INM) Version 3.10 to provide better simulation of aircraft performance.

Office of Commercial Space Transportation (OCST)

OCST provided regulatory oversight and inspection for eight launches (six successful, one partly successful, and one unsuccessful) in FY 1992. It issued two launch licenses to Engineering and Economic Research Systems, one a transfer from another company and the other a new operator's license, issued in August 1992. In March 1992, the Office published Federal Register Notice 92-4, "Commercial Space Transportation; Evaluation Criteria for Issuance of Vehicle Safety Approval for the COMET Reentry Vehicle System." The Commercial Experiment Transporter (COMET) is a new commercial space vehicle that returns to Earth after its space mission is completed. In May 1992, OCST published an environmental impact statement for commercial reentry vehicles. During the year, the Office represented DoT at international and domestic aerospace conferences and exhibitions and, among other duties, it administered and provided support for meetings and activities of the Commercial Space Transportation Advisory Committee and its working groups.

U.S. Environmental Protection Agency (EPA)

The EPA routinely conducted research and provided technical support using remote sensing as part of its overall environmental monitoring program. The agency used large-scale aerial photography to develop site characterization data during the remedial investigation and feasibility study conducted as part of remedial actions under the Comprehensive Environmental Response, Compensation, and Liability Act, as well as to support site selection and monitoring at hazardous waste facilities operated under the Resource Conservation and Recovery Act. In this connection, airborne multispectral scanner data and satellite imagery also played a part in helping engineers develop detailed site characterizations. The agency developed and used remote sensing systems to support the provisions of the Clean Air Act. Aerial photography and satellite data also supported a broad variety of pollution, global change, pollution prevention, compliance, and other ecosystem monitoring studies in FY 1992, such as those of critical-habitat areas for wildlife. In addition, the EPA was using and developing (with NASA support) light detection and ranging systems to monitor urban plumes and emissions sources as well as to measure levels of ozone, sulfur dioxide, and particulates. Finally, the agency was using a geographic information system for data integration and analysis in support of many of its programs.

National Science Foundation (NSF)

In 1992, astronomers at the National Radio Astronomy Observatory in Tucson, AZ, reported observations at millimeter wavelengths with the 12-Meter Telescope on Kitt Peak that have revealed the existence of a massive, gas-rich object at a distance of roughly 12 billion light years. It appears to be a galaxy in the process of formation. Using the 1,000-foot Arecibo radio telescope in PR, a staff member of the National Astronomy and Ionosphere Center discovered the first planets beyond our solar system. Since 1988 NASA has pursued the development of a new, long-duration ballooning capability, supported logistically by NSF. This capability takes advantage of the unique geographical, meteorological, and political situations offered by Antarctica. After several test flights, this new research opportunity reached the operational phase. During the austral summer of 1991-92, two experiments measured gamma and x-rays from solar flares as well as the composition and isotopic mass of heavy cosmic rays. The new ballooning technique has potential application in many fields, including astronomy and astrophysics; cosmic ray physics; auroral, ionospheric, and magnetospheric physics; and the chemistry and physics of the stratosphere.

Smithsonian Institution

The Smithsonian Institution has continued to contribute to the Nation's space goals in a variety of ways through basic research at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, MA, and at the Center for Earth and Planetary Sciences and the Laboratory for Astrophysics at the National Air and Space Museum in Washington, DC. For example, a scientist from SAO worked with data from both the Hubble Space Telescope and the International Ultraviolet Explorer to coordinate observations of Supernova 1992A. The outer shell of the exploded star seemed heavily laced with nickel and cobalt, suggesting unexpected outflow and mixing of materials from the interior or, perhaps, an initial explosion that extended to the exterior. Scientists from SAO, using data from the Roentgen Satellite on the Andromeda Galaxy, not only revealed stars undetected in High Energy Astronomy Observatory-2 (HEAO-2) images but also showed that many previously observed objects had changed in intensity over a decade, suggesting an unexpected variability in x-ray sources. Additionally, a group of international scientists at the SAO's Whipple Observatory in AZ achieved the first detection of gamma rays with energies equivalent to a trillion electron volts, coming from a source outside our own galaxy. In conjunction with AASE-II (mentioned above), reported results of lower-than-expected ozone losses over the Northern Hemisphere included data provided by an SAO-built far-infrared spectrometer flown aboard a NASA DC-8 in January-March quarter. The experiment also set new upper limits for hydrogen bromide in the atmosphere, a first step toward understanding the potential impact of ozone-threatening bromine compounds.

Department of State (DoS)

During 1992, the DoS supported Space Shuttle activities by providing a direct link to U.S. embassies in countries with emergency landing facilities. It participated in a first-ever coordinated NASA, U.S. Space Command, and DoS exercise to evaluate Space Shuttle Emergency Support Operations (Apollo Griffin). It also updated agreements in this area with The Gambia, Morocco, and Spain.

The DoS's Bureau of International Communications and Information Policy represented U.S. Government interests in the International Telecommunications Satellite Organization (INTELSAT) and the International Maritime Satellite Organization (INMARSAT). This Bureau also continued to further the interests of other, privately-owned international satellite companies. The dramatic retrieval and reboost of the INTELSAT VI (F-3) in May was a vivid capstone of successful cooperation among several U.S. agencies, private companies, and INTELSAT. During the year, INTELSAT launched another satellite and made decisions to procure three more. Seven other satellites were in production, with U.S. companies the prime contractors for all of these satellites. U.S. companies—Pan American Satellite and Columbia Communications—continued to make inroads into the international market by gaining permission to operate in a number of new countries. INTELSAT, in recognition of the inevitable growth in competition, moved to reduce the burden of treaty-mandated, *pro forma* reviews of such independent systems.

Reflecting the new relationship between the U.S. and Russia, Presidents Bush and Yeltsin signed a new space cooperation agreement at the Washington Summit in June 1992. Pursuant to the agreement, NASA and the Russian Space Agency established ambitious projects in manned space flight and planetary exploration. Also in FY 1992, the U.S. participated actively in the work of the U.N. Committee on the Peaceful Uses of Outer Space. DoS, supported by NASA, DoD, DoC, and DoE, managed U.S. involvement in a wide range of the Committee's activities, including the celebration of the International Space Year and the negotiation of non-binding principles on the use of nuclear power sources in outer space.

U.S. Arms Control and Disarmament Agency (ACDA)

During FY 1992, representatives of ACDA participated in the Delegation to the bilateral Defense and Space Talks (DST) with the former Soviet Union. At the June 1992 Washington Summit, Presidents Bush and Yeltsin agreed to work together to develop the concept for a Global Protection System to defend against limited ballistic missile attacks. U.S. and Russian high level delegations have met twice, in July and September 1992, to develop the concept for such a system as part of an overall strategy regarding the non-proliferation of ballistic missiles and weapons of mass destruction.

ACDA again this year was the lead U.S. agency at the Conference on Disarmament, at the United Nations First Committee, and on a United Nations Study Panel where confidence-building measures in outer space were discussed. Discussions at the Conference on Disarmament enhanced understanding but did not identify issues appropriate for multilateral negotiations. The United States abstained in a U.N. First Committee vote on a draft resolution on outer space arms control, introduced during FY 1992 by non-aligned states, because the resolution called for negotiations at the Conference on Disarmament on measures to "prevent an arms race in outer space." ACDA was also involved during the year with interagency committees on evolving Missile Technology Control Regime issues.

U.S. Information Agency (USIA)

The USIA explained U.S. space achievements to audiences abroad. It used a newly amalgamated system, Network System for TV and Radio (NETSTAR), providing new services in the area of broadcasting, such as Direct to Affiliate Digital Service. This service carried a new program, Worldsource, which delivered programs to broadcasters in Europe for retransmission on radio stations. The Voice of America (VOA) covered many facets of the U.S. space program in news stories, correspondent reports, and science documentaries. These features were carried in English and 46 other languages to audiences around the globe. The USIA also conducted a number of teleconference programs with foreign journalists and scientists. A USIA publication, *Dialogue*, a quarterly published in ten languages and distributed worldwide, featured such items as a striking picture of Venus from the Magellan space probe. The agency's Wireless File, which carries articles for placement in foreign periodicals, carried over 70 news stories and features on U.S. space achievements during the fiscal year. The USIA's WORLDNET satellite television broadcasting system, similarly, did 15 interactive dialogues on a host of space-related topics involving journalists and science writers around the globe and over 90 individual space-related segments on WORLDNET's Newsfile, which features 2 to 3 minute clips for placement on overseas television networks. Other USIA activities in this area included nine exhibits of Moon rocks in foreign cities and two U.S. astronauts who lectured abroad with USIA sponsorship.

Space Launch Activities

Space Shuttle Missions

During Fiscal Year (FY) 1992, the National Aeronautics and Space Administration (NASA) successfully completed seven Space Shuttle missions. These were, in order of flight, STS-44 (STS standing for Space Transportation System), STS-42, STS-45, STS-49, STS-50, STS-46, and STS-47.

STS-44 (using the Space Shuttle Atlantis) was a Department of Defense (DoD) mission that launched on November 24, 1991, from the Kennedy Space Center (KSC), FL. The primary objective of the mission was the deployment of a Defense Support Program satellite (see below under Space Flight and Space Technology). Atlantis landed safely at Edwards Air Force Base (EAFB), CA, on December 1, 1991.

The first flight of the new calendar year was STS-42 (Discovery), launched on January 22, 1992. This mission flew the International Microgravity Laboratory (IML), which included 16 countries' experiments in the behavior of materials and life in a nearly weightless environment. The Discovery returned safely to EAFB on January 30, 1992.

The next mission, STS-45 (Atlantis), began on March 24, 1992. Its primary objectives were to study the Sun, the upper reaches of the Earth's atmosphere, and astronomical objects using the Atmospheric Laboratory for Applications and Science (ATLAS-1)–a combination of instruments from the United States, France, Germany, Belgium, Switzerland, the Netherlands, and Japan to study the Sun and our atmosphere. NASA extended this flight an extra day to gather more scientific data. STS-45 returned safely to Kennedy Space Center (KSC) on April 2, 1992.

The first flight of the newest orbiter, Endeavour, was STS-49, which launched on May 7, 1992. This mission rendezvoused with, retrieved, and replaced the perigee kick motor of the INTELSAT VI (F-3) satellite, which the International Telecommunications Satellite Organization (INTELSAT) controllers then deployed into its intended orbit. Retrieving the satellite proved much more difficult than expected, resulting in 4 days of extravehicular activity. That effort made this flight the only one ever to have three astronauts walking in space at the same time. The Endeavour returned safely to EAFB on May 16, 1992.

STS-50 (Columbia) launched on June 25, 1992. In orbit for 14 days, this became the longest Shuttle mission yet flown. The Microgravity Lab on board studied effects of weightlessness on plants, humans, and materials. The Columbia returned safely to KSC on July 9, 1992.

On July 31, 1992, STS-46 (Atlantis) launched successfully. It deployed the European Retrievable Carrier (EURECA), which a subsequent Shuttle mission will retrieve in 6 to 9 months. The Shuttle crew also deployed the Tethered Satellite System (see below). Atlantis returned safely to KSC on August 8, 1992. In addition to their primary missions, all six of these Shuttle flights carried secondary payloads to support DoD experiments.

The final flight of FY 1992 was STS-47 (Endeavour), which launched September 12, 1992. This mission was a joint venture between NASA and the Japanese National Space Development Agency (NASDA), involving studies of the effects of weightlessness on life sciences and material processing. Endeavour returned safely to KSC on September 20, 1992.

Expendable Launches

Both NASA and the DoD employed numerous Expendable Launch Vehicles (ELVs) during the course of the year. Four of NASA's ELV missions successfully launched through the end of September, beginning with the Extreme Ultraviolet Explorer (EUVE) on a U.S. Air Force (USAF)-provided Delta II vehicle from Cape Canaveral Air Force Station (CCAFS), FL, on June 7. On July 3, a Scout vehicle launched the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) from Vandenberg AFB, CA. This marked the last launch of a NASA payload on the Scout, which has compiled an impressive record of 87.8 percent reliability in 115 launches since 1960, and 96.6 percent reliability in 88 launches since recertification in 1964. The remaining three Scouts in NASA's inventory will be used to support DoD launch requirements through 1993, after which NASA will end its Scout program.

On July 24, NASA conducted the first Delta II launch under a Medium ELV (MELV) contract with McDonnell Douglas, successfully placing the Geotail payload into orbit. Geotail is a joint project of the Japanese Institute of Space and Astronautical Science and NASA to investigate the geomagnetic tail region of the magnetosphere. The mission also carried the Diffuse Ultraviolet Experiment (DUVE), a secondary payload attached to the Delta second stage.

This was followed by the launch of Mars Observer (MO) on September 25, sending the spacecraft on its 1-year journey to the Red Planet. A commercial Titan III vehicle at Cape Canaveral boosted MO into low Earth orbit. Then a commercial Transfer Orbit Stage (TOS) placed it into its interplanetary trajectory. This mission was the last scheduled launch of a commercial Titan III for NASA and the first launch of the TOS commercial upper stage. The Air Force assisted with this launch, after which it began to convert the Launch Complex 40 facility at Cape Canaveral to a Titan IV/Centaur capability.

During FY 1992, NASA continued the pattern established with the Small ELV (SELV) and MELV contracts by initiating preparation of a competitive solicitation for Intermediate ELV (IELV) launch services to support its intermediate-class launch requirements into the next decade. The IELV procurement, like its predecessors, will include a mix of firm and optional missions. It will aggregate launch requirements into a quantity buy designed to maximize the business base for the successful offeror while providing the Government the cost advantages of economies of scale. NASA expects to release the IELV Request for Proposals to industry in November 1992.

NASA worked in 1992 to expand the ELV secondary payload program begun in 1991. Following DUVE in 1992, three additional NASA secondary payloads are manifested on USAF Delta II launches in 1993. There were several new proposals for secondary payloads in 1992, and NASA was analyzing available margin on future planned ELV launches as the year ended so as to identify flight opportunities for some of these payloads. The goal of the program is to maximize low cost flight opportunities. In the case of DUVE, for example, launch as a secondary on the Geotail mission provided the payload with significantly longer experiment time at about half the cost of a commercial-sounding rocket.

For the DoD in FY 1992, the Air Force launched four Delta IIs carrying Navstar Global Positioning System (GPS) satellites. The dates of these launches (using local times) were February 23, April 9, July 7, and September 9, 1992. The Air Force also launched the Delta II in support of NASA's EUVE on June 7 and supported two Delta II commercial launches on May 13 and August 31, 1992, plus another Delta launch on July 24. On December 7, 1991, meanwhile, the Air Force had achieved initial launch capability for the new Atlas II launch vehicle. This was a commercial launch by General Dynamics (GD) with support from the Air Force. On February 10 and July 2, 1992, the Air Force successfully launched two Defense Satellite Communications System (DSCS) satellites with the Atlas II, and it supported two other GD commercial launches on March 13 and June 9, 1992. A third GD commercial launch effort in August for the Galaxy IR satellite, also with Air Force support, was unsuccessful. When one of the two Centaur upper stage engines failed to spin up, causing the Centaur to tumble, controllers terminated the launch progression because the vehicle exceeded its safety envelope. At the end of the fiscal year, a failure investigation was still in progress. Additionally, in FY 1992 there was a single Atlas E launch on November 28, 1991, supporting a Defense Meteorological Satellite Program satellite, from Vandenberg AFB, CA. The Air Force also launched a Titan IV with a classified DoD payload on November 7, 1991, and on April 25, 1992, it launched a Titan II booster, likewise carrying a classified DoD payload, from Vandenberg AFB.

The Office of Commercial Space Transportation (OCST) in the Department of Transportation (DoT) provided regulatory oversight and inspections for six successful, one partially successful, and one unsuccessful launches in FY 1992, as shown in the table below:

Company	*Payload*	*Date*
EER Systems	Consort 4	11/16/91
General Dynamics	Eutelsat	12/07/91
General Dynamics	Galaxy 5	03/13/92
McDonnell Douglas	Palapa B-4	05/13/92
General Dynamics	INTELSAT-K	06/09/92
General Dynamics	Galaxy IR	08/22/92*
McDonnell Douglas	Satcom C4	08/31/92
EER Systems	Consort 5	09/10/92**

*Failed launch; see paragraph above.

**Second stage ended a few seconds early and the payload was disturbed by fluctuations, causing the microgravity portions of the experiments on board to fail, although other experiments were successful. (See also below under Space Communications and Commercial Development of Space Technology.)

Space Science

Astronomy and Space Physics

It is scarcely an exaggeration to state that from its earliest days, NASA has revolutionized the practice of space science, but this has been particularly true in recent years with the discoveries resulting from data sent back to Earth by NASA's spacecraft. FY 1992 proved to be a year of significant findings, highlighted by the results from NASA's **Cosmic Background Explorer** (COBE). In what may be one of the discoveries of the decade, the COBE team of scientists announced in April 1992 the discovery of the largest and oldest objects ever detected in the universe. These extremely faint ripples in the brightness of the cosmic background radiation stretch across the whole sky and contain the seeds from which the universe evolved. They show for the first time that the big bang was not perfectly smooth and uniform. Instead, it produced regions with differing temperatures, densities, and sizes–areas that would eventually evolve into the complex objects now seen in the Cosmos. The discoveries made by COBE, launched in November 1989, lend new support to the inflationary cosmology model, which states that the universe underwent a period of exponential expansion when it was only 10 to 35 seconds old. These findings seem to resolve one of the great mysteries of modern cosmology: what caused the big bang to result in planets, stars, galaxies, and clusters of galaxies.

In other advances in cosmology, astronomers at the National Institute of Standards and Technology (NIST) used data from the **Hubble Space Telescope** (HST) to measure the primordial abundance of deuterium–one of the very few available tests of the big bang theory of how the universe was formed all at once some 15 billion years ago from a point of immense density. Astronomers measured the deuterium abundance in interstellar gas by analyzing ultraviolet spectra of atomic hydrogen and deuterium. Using the Hubble's High Resolution Spectrograph built and managed by the Goddard Space Flight Center (and thus known as GHRS), they determined that there were 15 parts of deuterium per million parts of ordinary hydrogen, an amount suggesting less matter in the universe than many scientists believed. This indicates that the universe could continue expanding forever, as it has been doing since the beginning, according to the big bang theory.

The HST, NASA's first Great Observatory launched in April 1990, continued to produce other significant scientific data, resulting in the publication of more than 102 scientific papers by the end of FY 1992. Its discoveries included the first resolved image of a planetary nebula in a neighboring galaxy; striking images of a bright jet and the core of the giant elliptical galaxy M87, which provide evidence of a potentially massive black hole; clearly resolved observations of globular clusters of stars 100 times younger than ever seen before; the most distant gravitational lens ever seen; evidence for a massive black hole at the center of the nearby galaxy M32, weighing 3 million times the mass of the Sun; an image thought to be a ring of material fueling a black hole across the center of the spiral galaxy M51; observations of faintly flickering stars known as Cepheid variables, plus calculations of their distance–a first step in redetermining the expansion rate of the universe; coordinated data regarding Jupiter and its moons from HST and the international spacecraft Ulysses; confirmation of the continuing activity of volcanoes on Jupiter's moon, Io; and remote, unusual galaxies never before resolved by optical telescopes on Earth–perhaps interacting or merging embryonic galaxies.

Scientists also used the HST's GHRS to study stellar atmospheres. The GHRS had two hollow cathode calibration sources for on-board wavelength calibration using a platinum spectrum. NIST has measured the precise wavelengths of the platinum spectrum and incorporated that data into the calibration codes for the GHRS. Scientists have used the same data to calibrate the ultraviolet spectra obtained from the International Ultraviolet Explorer (IUVE) and other satellites. NIST scientists published a complete atlas of the platinum spectrum in 1992.

A Smithsonian Astrophysical Observatory (SAO) scientist also worked with both HST and IUVE, coordinating observations from both satellites of Supernova 1992A. These provided ultraviolet spectra identifying it as a Type Ia Supernova, probably a white dwarf. More interesting, the outer shell of the exploded star seemed heavily laced with nickel and cobalt, radioactive elements usually found at the core, thus suggesting unexpected outflow and mixing of materials from the interior or, perhaps, an initial explosion that extended to the exterior.

The second of NASA's Great Observatories, the **Compton Gamma Ray Observatory** (GRO) launched in April 1991, continued to be exceptionally productive scientifically as it conducted its all-sky mapping of the universe at gamma-ray energies. Its discoveries have added a whole new dimension to our understanding of the nature and location of gamma-ray bursts–mysterious, powerful objects emitting a thousand times more energy in gamma rays than our galaxy sends out at all wavelengths in fleetingly intense bursts. Compton's unique capability to pinpoint the location of the bursts has led to the discarding of the previously accepted theory for their origin and stimulated a flurry of theoretical activity to explain the observed spatial distribution of the underlying sources.

In a totally different area, Compton has provided a startling new discovery in extragalactic astronomy. Before the launch of Compton, only a small number of objects located beyond our galaxy were known to emit gamma rays. Compton has found that a number of quasars, previously known as intense emitters of optical and radio radiation, also exhibit intense emission of very high energy gamma rays. Using Compton, astronomers have detected a dozen such objects, providing a critical new clue to the nature of these most powerful sources of radiation in the universe. Compton has also provided new observations of phenomena that had been observed at lower levels of sensitivity in previous missions. It has provided unprecedented observations of gamma rays from solar flares and obtained the first "image" of the Sun in neutrons. It has also confirmed the existence of a diffuse glow of gamma rays resulting from the decay of large amounts of radioactive aluminum present in the disk of our galaxy, possibly produced by explosions of novae and supernovae during the past 10,000 years.

In 1992, in response to budget pressures NASA restructured the **Advanced X-ray Astrophysics Facility** (AXAF), the third of its four proposed orbiting Great Observatories. The restructured AXAF–consisting of two highly focused, smaller missions in place of the originally envisioned, larger observatory–will complement the observations made by the Hubble and Compton Observatories and will study stellar structure and evolution, large-scale galactic phenomena, active galaxies, quasars, and cosmology in the x-ray part of the electromagnetic spectrum. The first (imaging) mission may launch as early as 1998, while the second (spectroscopy) mission probably will follow a year later.

A fourth Great Observatory, the **Space Infrared Telescope Facility** (SIRTF), remained the highest priority in space astronomy, but fiscal constraints have compelled astronomers to reexamine its structure and content, resulting in substantial reductions in mission cost and complexity. While no formal developmental efforts for an infrared astrophysics mission will begin until sufficient funding is available, strong support for infrared science makes the initiation of SIRTF a viable goal during this decade. In the meantime, NASA has continued to make considerable progress in the development of infrared detector technology, a field pioneered by American industry, with substantial investment by the DoD and NASA, and one that is critical to both U.S. competitiveness and the success of future potential scientific missions.

Among NASA's other astronomical missions, the **Roentgen Satellite** (ROSAT), jointly funded with Germany and the United Kingdom, continued its scientific observations during FY 1992. Working in concert with the Compton GRO, it solved an almost 20-year-old mystery about the nature of the bright, gamma-ray source Geminga, clearly showing it to be a pulsar. Scientists were unclear about the source of Geminga's power and why it shined so brightly. Using data from the two satellites, they discovered that it was a rotating 300,000-year-old neutron star. In another application of ROSAT, NIST astronomers studied the extreme ultraviolet emissions from the hot coronae of active binary stars. These so-called RS Canum Venaticorum binary systems contain the most x-ray luminous stars that are cooler than the Sun; they provide an excellent laboratory for determining the physical processes that heat stellar coronae.

Meanwhile, ROSAT imagery of the Pleiades and Alpha Persei star clusters, obtained by scientists from the Smithsonian Astrophysical Observatory, provided new insights into the relationship between x-ray emission and the age and mass of stars, at the same time revealing many stars not seen in previous optical surveys. Similar ROSAT studies of the Andromeda Galaxy not only revealed stars undetected in High Energy Astronomy Observatory-2 (HEAO-2) images but also showed that many previously observed objects had changed in intensity over a decade, suggesting an unexpected variability in x-ray sources. Also, based on data from the HEAO-2 x-ray data, an SAO scientist and colleagues found strong evidence that Nova Muscae (a Southern Hemisphere star that exploded in 1991) was a binary system in which the primary star was probably a black hole.

Launched aboard a Delta II rocket from Cape Canaveral on the 7th of June, 1992, the **Extreme Ultraviolet Explorer** (EUVE), began its 6-month all-sky survey in July. Making observations of distant stars, collecting important information about their age, temperature, chemical composition, and energy level, EUVE was opening the virtually unexplored window in the electromagnetic spectrum between ordinary ultraviolet radiation and x-rays–the extreme ultraviolet. In 1993, once it finishes its 6-month task of determining the position, brightness, and temperature of all EUV-emitting objects, EUVE will begin a 12-month study of individual targets.

The first spacecraft in a new series of Small Explorers, the **Solar Anomalous and Magnetospheric Particle Explorer** (SAMPEX), launched on July 3, 1992, is designed to investigate anomalous cosmic rays (thought to be interstellar matter), galactic cosmic rays in the vicinity of Earth, solar energetic particles, and other phenomena of space physics. Among its instruments is a Heavy Ion Large Telescope from the Max Planck Institute for Extraterrestrial Physics in Germany. At the end of FY 1992, the spacecraft operated as planned, but it was still too early for the full significance of its data to be understood.

Yohkoh, a joint mission between NASA and Japan's Institute for Space and Astronautical Science (ISAS), has been operating as designed since its launch on August 30, 1991. Its prime mission is to study high energy phenomena in solar flares during the solar maximum. It collected scientific data throughout FY 1992. Comparisons of data from the joint U.S./Japanese Soft X-ray Telescope and the Japanese Hard X-ray Telescope are providing insights into the physics of solar flares, including their topology, energetics, and timing. For example, Yohkoh provided excellent coverage of the very large solar flare on November 15, 1991, while in December 1991 it obtained especially interesting observations of a small-loop flare.

The **Geotail** satellite, launched on July 24, 1992, is another joint mission with Japan. Its purpose is to study energy storage in the Earth's magnetic tail, stretched out on the night side of the Earth as a result of the solar wind. Instruments aboard the satellite are investigating the flow of energy and its transformation in the magnetic tail and then clarifying the mechanisms of input, transport, storage, release, and conversion of mass, momentum, and energy in the magnetic tail. In early September 1992, Geotail successfully executed its first lunar swingby that will enable the spacecraft to orbit on the night side of the Earth. Following the lunar swingby, controllers successfully deployed the spacecraft's antennas, beginning the collection of scientific data. Geotail is the first mission in the International Solar-Terrestrial Physics initiative, an effort to derive the physics of the behavior of the solar-terrestrial system so as to predict how the Earth's atmosphere will respond to changes in the solar wind.

Launched on October 6, 1990, Ulysses is a cooperative European Space Agency/NASA mission to study the unexplored polar regions over the Sun. On February 8, 1992, Ulysses flew by Jupiter, successfully using the gravity of the largest planet in our solar system to make a nearly 90 degree turn "south" into the required polar orbit over the Sun. While flying close to Jupiter through its intense magnetic and radiation fields, Ulysses made a number of discoveries about the Jovian environment: (1) the belt of ions around Jupiter, trailing in the orbit of its volcanic moon, Io, was patchy and variable in its density and radio emission; (2) there was a "polar hole" in the magnetosphere where radiation levels were low; (3) auroral-type radio emission and intense streams of ions and electrons occurred on the high-latitude, evening side of Jupiter; (4) the ions in the magnetosphere could generally be identified by their composition as coming from Jupiter's ionosphere, Io, and the solar wind; (5) the magnetic field on the evening side was being dragged back into Jupiter's magnetotail by the solar wind. Ulysses was scheduled to arrive at the southern solar latitudes in mid-1994 and the northern latitudes in mid-1995.

The **Tethered Satellite System** (TSS), a cooperative program between NASA and the Italian Space Agency, flew aboard the Space Shuttle Atlantis (STS-46), launched July 31, 1992. The TSS was an effort to demonstrate, study, and develop the technology of large tethered structures in space. The objectives of TSS-1 were to determine and understand the electromagnetic interaction between a satellite tethered to the Shuttle and the ambient space plasma; to investigate and understand the dynamic forces acting upon a tethered satellite; and to develop the capability for future tether applications. Due to problems with the deployment mechanism and the tether, the Atlantis crew was able to deploy the tethered satellite to only 256 meters instead of the goal of 20 kilometers. Although none of the primary scientific objectives could be achieved, TSS-1 provided important data. For example, the TSS was more stable than predicted due to natural damping of the satellite/tether system; measurements of induced voltage and current verified predicted values; and all satellite systems worked as planned. The limited deployment also provided encouraging results for SAO experiments designed to test electrodynamic processes in the upper atmosphere and the forces affecting a tethered payload. As the year ended, NASA was investigating the cause of the deployment problems. Preliminary analysis suggested it was a 1/4-inch diameter bolt that prevented part of the reel mechanism from travelling back and forth.

Voyagers 1 and 2, launched in 1977, and **Pioneers** 10 and 11, launched in 1972 and 1973 respectively, continued to send back data. During FY 1992, they were exploring the solar wind, magnetic fields, and cosmic rays in the outer reaches of the solar system. They have confirmed that the 22-year magnetic cycle of the solar magnetic field extends to beyond the orbit of Pluto. Scientists were planning for encounters with the shock wave and "heliopause" at the outer edge of the solar wind, and for penetration into the interstellar gas. The Voyagers will be the first spacecraft to pass through this region, which scientists believe existed somewhere from 5 to 14 billion miles from the Sun.

In addition, as part of the **Astrophysics and Space Physics Sub-orbital Program**, rockets, balloons, and aircraft provided NASA a means to make preliminary observations, conduct selected low-cost investigations, test instrumental concepts, and train the next generation of scientists and engineers how to develop instruments for future space missions. In 1992, NASA supported approximately 40 balloon flights, 40 sounding rocket launches, and more than 350 flights on its research aircraft. For example, the Kuiper Airborne Observatory (KAO–a C-141 Starlifter at Ames Research Center, equipped with a 0.97-meter telescope) flew more than 60 research flights. At last count, more than 49 researchers had earned Ph.D.s using the KAO for their research.

In **Other Areas of Astronomy**, NIST scientists completed model studies of gravitational wave emissions during the slow in-spiral of compact stars to massive black holes that are hypothesized to be the nuclei of galaxies. The results, while dependent on a number of assumptions such as the density of stars in a galactic nucleus, suggest that such sources may be observable from an orbiting gravitational wave observatory.

NIST scientists have also constructed the first stage of a vibration isolation system for the NSF-sponsored Laser Interferometric Gravitational Observatory complex, consisting so far of separate observatories in WA and LA plus two being built in Europe. The system may be used to upgrade vibration isolation of the mirrors in four large terrestrial gravitational wave detectors in the U.S. and Europe.

NIST spectroscopists have made precise measurements of wavelengths and isotope shifts for ultraviolet transitions of doubly-ionized mercury to satisfy NASA requirements for more accurate atomic data. NASA's need arose from an observation by the Goddard Space Flight Center of the star "chi Lupi" using the HRS aboard HST. Use of previous wavelength and isotope shift data for mercury proved inadequate for NASA astronomers to interpret the stellar data. Using the new NIST data, astronomers discovered that chi Lupi's atmospheric mercury is virtually all an isotope, mercury-204, that constitutes only 7 percent of terrestrial mercury. This result disagreed with predictions of stellar atmospheric theory, thereby providing scientists with important new information for understanding the evolution of heavy element abundances in stars and interstellar media.

Additionally, a group of international scientists at the SAO's Whipple Observatory in AZ achieved the first detection of gamma rays with energies equivalent to a trillion electron volts, coming from a source outside our own galaxy. The source, Markarian 421, a compact object about 400 million light years from Earth, was first detected by NASA's Compton Gamma Ray Observatory (GRO), but at energy levels some 1000 times lower.

Also during 1992, astronomers at the National Radio Astronomy Observatory (NRAO) in Tucson, AZ, reported observations at millimeter wavelengths with the 12-Meter Telescope on Kitt Peak that have revealed the existence of a massive, gas-rich object at a distance of roughly 12 billion light years. It appears to be a galaxy in the process of formation. Astronomers first saw the object in the infrared and then identified it with an optical emission source exhibiting highly redshifted spectral lines. The NRAO observers have detected emission lines of the carbon monoxide molecule as well as those of neutral atomic carbon. These spectral lines are signatures of star formation processes. The mass of molecular gas in this object, as inferred from the observations, is roughly 1,000 times that of the Milky Way, or a trillion times the mass of the Sun. This has led astronomers to conclude that they have seen this object at an early point in its history, before the bulk of the gas has been assembled into stars.

Using the 1,000-foot Arecibo radio telescope in PR (the world's largest and most sensitive single telescope for collecting radio signals from space), a staff member of the National Astronomy and Ionosphere Center discovered the first planets beyond our solar system. Strikingly, the two planets discovered do not orbit a normal star like the Sun; instead, they circle a neutron star called PSR1257+12, a 10-mile-diameter stellar remnant as dense as the nucleus of an atom. The masses of the two planets are 2.8 and 3.4 Earth masses, and they orbit the neutron star every 98.2 and 66.6 days, respectively.

At the Kitt Peak National Observatory in Tucson, AZ, scientists have obtained images of 15 extremely distant quasars. These images showed extended nebulous emission associated with the quasar point source; they have typical sizes of 5 times the diameter of the Milky Way and typical radiated power of 50 billion suns. Their optical features are elongated, with the axis of elongation aligned with observed radio emission (previously the only spatially resolved feature associated with distant quasars). This implies the existence of a gas cloud around the quasar that contains up to a trillion solar masses of gas.

In preparation for proposed observing programs for the European Space Agency's Infrared Space Observatory, scheduled for launch in 1993, members of the Laboratory for Astrophysics at the Smithsonian National Air and Space Museum (NASM) analyzed coronal lines from highly ionized atoms in the spectra of novae and galaxies; they discovered that some might be radiated as lasers and masers, especially in active galaxies. Scientists were conducting similar analyses of hydrogen and maser activity observed in stellar disks.

Solar System Exploration

Not just the study of the wider universe but also of our own solar system has continued to be an important focus of American science. One of the highlights of efforts in this direction during FY 1992 was the continuing flow of exciting results from NASA's **Magellan** spacecraft. Magellan's mission, since its launch aboard the Space Shuttle Atlantis in May 1989, has been to map the surface of Venus and explore the planet's interior structure. During FY 1992, Magellan completed its second and third 243-day mapping cycles. By the end of September 1992, the spacecraft had successfully mapped over 99 percent of the planet's surface at least once and had produced stereoscopic observations of about 23 percent of the surface. In late September, Magellan began to acquire full-time gravity data. Throughout the fourth cycle, it will continue to collect data on Venus' gravity field. Termination of spacecraft operations is projected to occur on May 15, 1993.

Using radar images from Magellan, the U.S. Geological Survey, under charter from NASA, has begun to provide maps that support scientific studies of the geological properties of Venus. It has designed a succession of general and specialized maps to this end and will formally publish them in their "preliminary" forms in an attempt to provide timely access to the massive Magellan data for students of Venus. These maps are preliminary in the sense that they represent incomplete, early-generation data, but the Survey has processed these data to the fullest practical extent before converting them into formal maps. Formal mapping will continue for many years after Magellan's closeout occurs.

Galileo, the first mission to perform a close, continuous study of Jupiter, began its 6-year trip to the solar system's largest planet on October 18, 1989. On October 29, 1991, Galileo passed within 1,600 kilometers (1,000 miles) of asteroid 951, Gaspra, providing the world with its first close-up observations of the asteroid, displaying craters and ridges as small as 180 feet. This showed that despite a stuck main antenna, the spacecraft can return good data from Jupiter. During its encounter with Jupiter beginning in 1995, Galileo's instruments will conduct detailed studies of the Jovian system, including the planet, its ring, its four major moons, as well as the structure and physical dynamics of the planet's magnetosphere. The Galileo entry probe will make measurements deep inside Jupiter's atmosphere. The available low-gain antenna system should allow the spacecraft to complete 70 percent of its projected Jovian studies even if planned efforts to free the high gain antenna do not succeed.

Mars Observer (MO), a single spacecraft that will enter a near-polar orbit around Mars in August 1993, successfully launched from Cape Canaveral Air Force Station, FL, aboard a Titan III/Transfer Orbit Stage (TOS) combination on September 25, 1992. MO will perform the first detailed study of the red planet since the Viking missions in 1975-6. Following the launch, the spacecraft and instruments completed a preliminary checkout, and all systems were functioning well as the year ended. Instruments on the spacecraft will map and study the entire surface and atmosphere of Mars for a full Martian year (687 Earth days), beginning late in 1993 after insertion into Martian orbit. These observations will determine the planet's global chemical and mineral surface composition and will provide a thorough exploration of Mars' atmosphere, gravitational field, topography, and magnetic field. In addition, MO carries a radio relay system, provided by France, to send back data from surface packages to be deployed on Mars by Russia's Mars-94 mission, scheduled to arrive at Mars in late 1995.

In related developments, during 1992, the U.S. Geological Survey completed topographic mapping of Mars at four different scales, using previously acquired Viking Orbiter images. The Survey also derived a digital elevation model of Mars. These products supported the MO mission and were being used by planetary scientists to reach a better understanding of the geologic processes on Mars. The Survey has also prepared the first Compact Disk–Read Only Memory (CD-ROM) optical disks containing planetary cartographic data. These disks contain geometrically registered digital image mosaics (made from Viking Orbiter images) and a digital topographic model of Mars. They permit scientists and mission planners to examine interactively the character and structure of the Martian surface, and they provide a compact delivery medium of data for geographic information system applications and compilation of special map products.

Cassini, a joint endeavor with the European Space Agency, will conduct a comprehensive scientific investigation of the Saturnian system, including the planet's rings, moons, and magnetosphere. Constraints on the FY 1993 budget led to the cancellation of the Comet Rendezvous Asteroid Flyby (CRAF) portion of the CRAF/Cassini program and necessitated a 2-year delay in the Cassini launch. In addition, NASA initiated and executed a restructuring of the Cassini program during FY 1992. The goals of this restructuring included maintaining the program's scientific viability, mission-unique capabilities, and high potential for discovery, while reducing the developmental costs of the program. The launch is scheduled to be aboard a Titan IV ELV in October 1997, with arrival at Saturn expected in 2004.

Pioneer Venus Orbiter (PVO), launched on May 20, 1978, continued to operate for over 14 years, collecting an impressive set of data on our sister planet, including the first maps of the surface of Venus using a radar altimeter and thousands of pictures of the planet's cloud patterns. Originally designed to operate for just one 243-day period, the spacecraft displayed a longevity surprising even to its designers. During FY 1992, PVO continued collecting data on the planet's atmosphere and surface. In August and September, it completed a number of maneuvers to maintain its orbit for as long as possible given the remaining on-board propellant. These maneuvers brought the spacecraft down into parts of the planet's atmosphere lower than had ever been reached before, enabling scientists to conduct additional studies of the chemical and physical processes of Venus' upper atmosphere, especially its interaction with the solar wind. PVO ceased transmitting just after the end of the fiscal year, on October 8, 1992.

Other Space Science

As NASA prepares to extend human presence beyond Earth's orbit in the 21st century, there is an increased need for expanded knowledge about the role of gravity on living systems. Using Spacelab, a reusable modular laboratory developed by the European Space Agency (ESA) for installation in the Space Shuttle cargo bay, the 8-day **International Microgravity Laboratory** (IML-1) mission launched on January 22, 1992, was the first in a series of NASA flights dedicated primarily to microgravity and life sciences research. Through 6 international space science research organizations in 14 countries, more than 220 scientists from around the world collaborated on the IML-1 mission. The Space Shuttle crew, including payload specialists from Canada and Germany (representing ESA), conducted 42 experiments in life and materials sciences. These investigations studied how conditions in space affect terrestrial life forms, including humans, insects, plants, and individual cells. Results of these investigations will expand the knowledge of how life forms adapt to weightlessness and respond to cosmic radiation. Scientists will use these results to develop measures that enhance the quality of life on Earth and in space, as well as to counter potentially harmful physiological responses to microgravity. Investigations in the area of materials science concentrated on crystallization, casting and solidification technology, and on condensed matter physics.

The **United States Microgravity Laboratory** (USML-1), launched June 25, 1992, was the first Spacelab flight dedicated solely to microgravity research. Over 30 investigations made up the payload, covering 5 basic areas: fluid dynamics, crystal growth, combustion science, biological science, and technology demonstrations. This flight served as a "dress rehearsal" for Space Station Freedom and the knowledge gained from the investigations will assist NASA in preparing for work on Freedom later in the 1990s. It was the longest Shuttle flight to date, lasting 14 days, and used the Extended Duration Orbiter Medical Program to ensure crew health and safety. This involved Spacelab, middeck, and pre- and post-flight investigations to assess the medical status of the crew.

Spacelab J (SL-J), launched on September 12, 1992, was a reimbursable mission with Japan to conduct low-gravity research in the broad disciplines of microgravity and life sciences. Seven of the NASA-sponsored experiments were in the field of life sciences and two were in materials science. Japan provided 34 experiments plus two that were joint. The flight crew included a Japanese payload specialist to assist with the experiments. The life sciences research collected data on human adaptation to low gravity, explored the effects of microgravity and radiation on living organisms, and gathered data on the fertilization and development of organisms in the absence of gravity. Investigations in microgravity science concerned the disciplines of biotechnology, fluid physics and transport phenomena, combustion science, and acceleration measurement. All of these investigations will add to the base of experience for the operation of Space Station Freedom.

To expand such efforts, on July 12, 1992, **NASA and the National Institutes of Health** (NIH) signed an interagency agreement for cooperation in biomedical research. The agreement aims at expanding access to and stimulating new opportunities for research in space for the biomedical research community. NIH will have the lead role in ground-based work, while NASA will have the lead in space flight research. The agreement also provides for a special joint program of space flight experiments to enable greater numbers of biomedical and behavioral scientists access to space. Areas of emphasis at the end of FY 1992 were the neurosciences, musculoskeletal physiology, and biotechnology. Additional areas under consideration included cardiopulmonary physiology and immunology. A major theme for cooperation was the use of the unique environment of space and the technological impetus provided by the space program to help solve medical problems on Earth.

Since 1988, in a totally different area of space science, **NASA** has pursued the development of a new, long-duration ballooning capability with NSF's logistical support. This capability takes advantage of the unique geographical, meteorological, and political situations offered by Antarctica. After several test flights, this new research opportunity reached the operational phase. During the austral summer of 1991-92, two large, high-altitude balloons ascended from McMurdo, Antarctica. Each balloon made more than one complete circumnavigation of the South Pole while remaining above 99.5 percent of the Earth's atmosphere. The first balloon went up on December 16, 1991, and flew at altitude for nearly 10 days before parachuting back to Earth at radio command. The experiment measured the composition and isotopic mass of heavy cosmic rays by using a large, superconducting magnet to deflect the trajectories of the particles. The principal investigators were from Boston University and the University of Utah.

The second balloon ascended on January 10, 1992, and flew for nearly 13 days, after which commands returned it to Earth. By using large, cooled germanium detectors, the experiment measured gamma and x-rays from solar flares. The investigators from the Berkeley and San Diego campuses of the University of California plan to improve the experiment and refly it during the austral summer of 1992-93. Constant solar heating and the continuous view of celestial objects make Antarctic long-duration ballooning much more effective than similar efforts at mid-latitudes. The new ballooning technique has potential application in many fields, including astronomy and astrophysics; cosmic ray physics; auroral, ionospheric, and magnetospheric physics; and the chemistry and physics of the stratosphere.

Space Flight and Space Technology

Space Shuttle

The Space Shuttle's primary purpose remained in FY 1992 to transport people and cargo safely into low-Earth orbit (100 to 350 nautical miles above the Earth). As of the end of the year, there were four active Orbiters: Columbia, Discovery, Atlantis, and Endeavour. Each one could accommodate up to seven crew members. Typical missions have ranged from 4 to 9 days in duration, with crews numbering from five to seven. The newest orbiter, Endeavour (OV-105), had its first flight in May 1992. New improvements to the fleet begun since the end of FY 1991 included a solid state star tracker and an enhanced master events controller. In addition, work continued in 1992 on the Extended Duration Orbiter (EDO). During June 1992, an EDO mission on Columbia recorded the first 14-day orbit on a Shuttle mission. In cooperation with its international partners, NASA continued to develop and deploy hardware for use on Shuttle missions. For example, it used Spacelab carrier system hardware on the International Microgravity Laboratory (IML) and Spacelab-J missions. Also during FY 1992, many material and life science studies looked towards producing new materials, improving known processes, and developing new ones.

The Space Shuttle Main Engine (SSME) program continued its aggressive test activity during 1992, as well. Engineers conducted more than 100 ground tests, accumulating more than 36,000 seconds in support of development, certification, and flight programs. The Block II controller completed certification and operated for the first time in April. This component has demonstrated a greatly reduced failure rate over the Block I while providing superior performance in memory capacity, fault detection, and accuracy of measurement. For the first time this year, NASA also certified and flew an improved High Pressure Fuel Turbopump, which increased its time between overhauls from three to four flights to eight to nine. Moreover, the Technology Test Bed Program completed the initial SSME test series, designed to characterize the internal operating environments and complete the first full-scale testing of a turbopump featuring liquid oxygen feed and hydrostatic bearings in an SSME-class engine.

Meanwhile, NIST developed and tested cryogenic flowmeters for the SSME fuel and oxidizer (LOX) ducts. As the year ended, the LOX meters were scheduled to be tested on the Technology Test Bed engine at Marshall Space Flight Center. More generally, to improve current propulsion systems and achieve the performance demands of future propulsion system designs, NIST engineers were characterizing new materials that reduce friction and wear. NIST was testing new materials, including ion-implanted surfaces and coatings such as Diamond-Like-Carbon (DLC), for aerospace bearing systems. The work at NIST on DLC coatings showed an order of magnitude lower friction and two orders of magnitude lower wear than for 440C stainless steel (the material used until now on the SSME). NIST has recently completed work on the wear rate and coefficient of friction for 440C, encompassing the range of speed, load, and temperature thought to exist in the SSME. NIST was also investigating the tribology of Si_3N_4 ceramic/DLC couples for aerospace applications.

The **Advanced Solid Rocket Motor** (ASRM) program made significant progress during FY 1992 in facility construction and motor design. The expectation is that the new motor will increase safety and reliability, improve performance of the booster, and improve overall efficiency of operation. Except for the Yellow Creek facility at Iuka, MS, which was 96 percent designed, architects completed all of the facility design. Construction was about 30 percent completed at the end of the fiscal year, with the Babcock and Wilcox facility at Mount Vernon, IN, in operation on time and under budget. The ASRM program has also made significant technical progress in designing, building, and testing hardware. A preliminary design review held in March identified no issues that would impede the progress of the program. ASRM engineers have conducted six successful subscale (48-inch diameter) solid rocket motor static firings to evaluate nozzle and insulation development. The program also carried out 11 live-propellant, continuous-mix pilot plant runs, resulting in properties for propellant materials equal to or exceeding requirements. Five case segments have been completed, with 42 others in various stages of completion. The Babcock and Wilcox facility successfully welded and heat treated some of these case segments (150-inch, short length cylinders).

The **Solid Rocket Booster** continued to perform without significant problems in seven Shuttle flights during FY 1992. There was one static test firing of a motor manufactured before the Challenger accident that was used to qualify a new igniter design with improved seals. There was also one static test firing of a production configuration motor used to qualify the new igniter design and to verify the constancy of manufacturing processes. Activities have begun towards development of a new, non-asbestos insulation material to replace asbestos-containing materials in the existing motor as well as towards the developmental testing of a design modification to the aft skirt, which will improve its structural safety.

In the area of **Shuttle Systems Integration**, the Day-of-Launch I-Load-Update (DOLILU-I) system operated throughout all missions during FY 1991. This system took into account the actual winds on launch day and updated the pitch and yaw software directions to improve the Shuttle's ascent trajectory significantly. This has reduced structural loads during ascent, thereby providing a higher probability of launch. Development of the DOLILU-II system further improves the ascent trajectory by uplinking, on the day of launch, the main engine control tables, solid rocket trim data, and aerodynamic control data. This improved system should be certified by the end of 1993 and operational starting in 1994.

Relatedly, in FY 1992, NASA space technology researchers put a **Ground Processing Scheduling System** into use to help reduce the cost of processing and readying each Shuttle for its next flight. Using artificial intelligence, the system maintains schedule efficiency by predicting scheduling conflicts. Its use saved $182,000 for STS 50 alone and could result in an annual savings of approximately $1,700,000 annually in time spent at scheduling meetings and in making paper schedules. In another achievement, NASA's transportation technology program successfully completed a series of tests on an advanced fabrication technology that can significantly lower the cost and time for fabricating combustion liners for future rocket propulsion systems. Combined with a new technique for casting the structural outer shell of the main combustion chamber, this technology offers savings in production time of approximately 3 years. The estimated cost savings from this technology is 85 percent of the current cost for fabricating a main combustion chamber for the SSME.

New Launch System (NLS)

On April 16, 1991, Vice President Quayle and the National Space Council directed NASA and the DoD jointly to pursue the development of a new space launch system with the objective of achieving significant improvements in reliability, responsiveness, and operational efficiency. The goal for the New Launch System (NLS) was for it to be uncrewed but human-rateable and to offer reductions in launch costs. National Space Policy Directive 4, issued on July 10, 1991 (see Appendix F of last year's report), further reinforced these objectives, stipulating that NLS would provide a range of launch capabilities and be susceptible to change as requirements evolved and new technology became available. The NLS program underwent a detailed review in FY 1992 in order to define its requirements and ensure that its baseline vehicles were meeting the Nation's civil, military, and commercial launch needs. The Air Force and NASA determined that the modular family of vehicles needed only to span the range from the medium launch vehicle class to a booster supporting Space Station Freedom's resupply missions. As a result, the program deleted the NLS-1 vehicle (135,000 pounds to low-Earth orbit). The NLS-2 vehicle (50,000 pounds to low-Earth orbit) and the NLS-3 (20,000 pounds to low-Earth orbit) remained unchanged. The review modified the propulsion system, the upper stage, the cargo transfer vehicle, and the facilities, but they remained in the baseline program. As a result of these changes, NLS development costs declined by $1 billion. From a hardware standpoint, the program defined the Space Transportation Main Engine (STME) as designed to be operable, low-cost, and highly reliable. At the end of the year, the NLS program was ready to send out a request for proposals in early 1993 for engine development.

In separate tests, NIST demonstrated that the liquid hydrogen (LH_2) tank to the LH_2 pump duct of the STME could be cooled by passive recirculation rather than by venting gaseous hydrogen (GH_2) from the pump end during cool-down. Also, during 1992, NASA's transportation technology program completed development of a new turbopump bearing for the STME. This bearing provides the advantage over the current state-of-the-art technology by offering essentially unlimited life and durability through creating a fluid film that provides shaft support inside the turbopump. The new design will help produce a lower cost and lighter weight turbopump for STME as well.

Other Launch Systems

The **Pegasus** booster, developed by Orbital Sciences Corporation and the Defense Advanced Research Project Agency (DARPA), was a three-stage, solid-propellant, inertially guided, winged launch vehicle that was nearing fully operational status in FY 1992. An optional hydrazine-propelled fourth stage could be added as required for additional performance or precision orbital injection. Launch procedures for the Pegasus involved being carried aloft by a conventional transport or bomber aircraft and released at 40,000 feet, where the first-stage motor ignited. As the year ended, the payload fairing was undergoing redesign to resolve problems identified in the last flight on July 17, 1991, and to improve reliability and contamination control for future flights. At the conclusion of ground testing of these modifications, DARPA planned to transition the program to the Air Force. The next flight of the booster was expected in the second quarter of FY 1993. As FY 1992 ended, a new version of the booster called Pegasus XL was under development in a jointly managed effort between the Air Force and NASA. The XL offered increased performance in that a payload of 500 pounds (up from 430) could be boosted to a 400 nautical mile polar orbit by stretching the length of the original Pegasus' first and second stages. The Air Force was acquiring Pegasus XL for launch of Space Test Program payloads. The first Air Force launch of Pegasus XL was scheduled for the first quarter of FY 1994.

The **Taurus** standard small launch vehicle capitalized on DARPA's previous investment in the Pegasus air-launched vehicle to produce a ground-launched rocket with greater payload capacity. Taurus used the three Pegasus solid rocket motors (with the wing removed) stacked atop a Peacekeeper first stage to construct a vehicle capable of placing 1,900 pounds into a 400 nautical mile polar orbit. Taurus was fully road-transportable and could operate from austere launch sites independent of existing space launch centers. Requiring only a bare concrete pad, the Taurus team could establish a launch site within 5 days of arrival. The rocket then required only an additional 72 hours for final preparation and launch operations. This capability will provide assured access to space for moderate-sized payloads despite hostile action or natural disasters that could deny the use of existing facilities. The rocket passed a major milestone this year with the successful integration and testing of the full-scale engineering vehicle, which was identical to a mission-ready rocket except that the solid rocket motors were filled with inert propellant. Contractor and DARPA personnel validated stacking procedures and conducted flight simulations as part of this critical test. They will conduct this engineering vehicle integration–known as a pathfinder operation–three more times, including once at the actual launch site, before beginning preflight operations with live motors. The first launch was scheduled for 1993.

The **Inertial Upper Stage** (IUS) continued to be the most accurate upper stage in the Air Force inventory. Without IUS, a Titan IV delivered the Defense Support Program (DSP) Spacecraft to low-Earth orbit at about 150 nautical miles, whereas after launch from a Space Shuttle, two different burns of the IUS solid stages produced a geosynchronous orbit at over 22,000 nautical miles. The Air Force planned for the IUS to continue to support the DSP into the next century. Additionally, the Air Force would continue to support NASA by procuring IUSs to support upcoming Shuttle missions, such as the launches of the Tracking, Data, and Relay System (TDRS) spacecraft.

The Navy was considering use of a cooperative research and development agreement as the primary mechanism for completing the development of the **Sea Launch and Recovery** (SEALAR) system. SEALAR offered the potential for a low cost, fully reusable, two-stage vehicle. Launched at sea, it would provide a very attractive blend of responsiveness, flexibility, and environmental acceptability not associated with more traditional launch concepts.

Satellites

The **Navstar Global Positioning System** (GPS) was a space-based, radio-navigation system satisfying requirements for highly precise, worldwide, three-dimensional position, velocity, and timing data for military (and secondarily, civilian) aircraft, ships, and ground operations. The system consisted of user, satellite, and control segments. GPS satellites operated in inclined, semi-synchronous (i.e., 12-hour) orbits. At the end of FY 1992, the system was still being deployed, with four operational GPS satellites (Block IIA) launched during the year. In 1992, approximately 80,500 DoD receiver terminals were on order or in use. The system's control segment updated the satellite broadcasts, which provided positional accuracies to within 16 meters for military users and to 100 meters for civilian users.

Initial deliveries of user equipment to all three armed services began in 1989. Their installation was well along on many different ships and aircraft at the end of FY 1992. The then-existing mix of four developmental and 15 operational satellites provided worldwide, two-dimensional coverage 24 hours a day and worldwide, three-dimensional coverage at least 21 hours a day; the completed constellation of 24 satellites will provide full-time, three-dimensional navigational information covering the entire globe.

In a related development, DARPA took delivery of its first two miniature GPS receivers this year. These space-qualified devices weighed only 8 pounds and required only 12.5 watts of power. They will permit satellite navigation to an accuracy of 4 meters without interaction with satellite ground stations. The flight demonstration of these receivers, scheduled for 1993, will be a key step in increasing satellite autonomy. Such operation by the satellite, independent of ground contact, should contribute greatly to reduced life-cycle costs in future space systems.

More generally, DARPA's **Advanced Space Technology Program** (ASTP), of which the miniature GPS receivers were a part, has sought to develop leading technologies to enhance the performance, capabilities, survivability, and accessibility of military space systems while simultaneously minimizing the size, weight, cost, and power consumption of these systems. The generic space technologies being pursued by DARPA will be applicable to both large and small defense satellites and, additionally, they may benefit other sectors of Government space endeavors. DARPA has sponsored over 40 advanced space technology projects during the past few years, many of them completed this year.

The **Defense Support Program** (DSP) provided a highly available, survivable, space-based surveillance system to detect and report missile and space launches as well as nuclear detonations in near real time for the National Command Authorities. The DSP system consisted of a constellation of satellites in geostationary orbits, fixed and mobile ground processing stations, one multi-purpose facility, and a ground communications network. On November 24, 1991, the crew of Space Shuttle Atlantis (STS-44) and an IUS successfully launched an enhanced DSP satellite, the third in the DSP-I block of satellites. This DSP satellite completed an on-orbit check-out and became operational 25 days after launch–5 days ahead of schedule. DSP-I satellites will provide the DoD with enhanced missile warning and surveillance capabilities. They include a second-color focal plane array and a mission data message rebroadcast capability.

In 1992, the Air Force had several modernization projects underway to sustain and improve DSP's warning and surveillance capabilities. These projects included the replacement of obsolete hardware associated with the reception, transmittal, and recording of satellite data at the fixed ground stations; of data processing computers at the fixed ground stations; of mission processing and support software to enhance capabilities and supportability at the fixed ground stations; and an upgrade of DSP's survivable mobile ground system to enhance survivability and compatibility with the DSP-I block of satellites. These projects will allow DSP to maintain a viable warning capability until it is replaced by the Improved Space-Based, Tactical Warning/Attack Assessment (ISB, TW/AA) system (previously known as Follow-On Early Warning System) in the next decade.

This **ISB, TW/AA** system will capitalize on the infrared sensor technology developed since the first DSP satellite went into orbit 2 decades ago. The new system will be intended to provide a high probability of detection against the threats of the future, characterized by shorter-range and dimmer missile launches deployed in numerous third-world countries around the world. The ISB, TW/AA system will be designed to meet this threat with continuous, worldwide coverage. It will also provide quicker warning messages to the field commanders than DSP offers. Engineers will design the satellites for longer lifetimes to reduce life-cycle cost and will use crosslinks to eliminate overseas ground stations. Through these design improvements, the ISB, TW/AA system should be ready to support future conflicts anywhere with just a moment's notice. (See also coverage below of DoD communications and meteorological satellites.)

A new satellite named **ALEXIS** (Array of Low-Energy X-ray Imaging Sensors) was the first such spacecraft developed and integrated by the Los Alamos National Laboratory, NM. Just a concept in 1988, ALEXIS was ready for launch in the late summer of 1992 but had to wait until Pegasus was fully operational. Then, the Air Force was scheduled to provide launch aboard a Pegasus air-launched booster (see above). Collaborating with Los Alamos on this project were the Department of Energy's Sandia National Laboratories; the Berkeley Space Sciences Laboratory; Ovonics, Inc.; and AeroAstro, Inc. ALEXIS will allow scientists to demonstrate a wide-field, ultrasoft X-ray telescope, determine the background signals that might fool the telescope, and observe astrophysical objects. It will also allow a study of ionospheric effects on the discrimination and distortion of very-high-frequency signals originating from the Earth. Furthermore, it will permit Los Alamos scientists to apply small satellites to many problems in technology development for basic research and national security.

In the area of **Technology Supporting Space Science**, final tests of metal meshes, developed by the National Air and Space Museum in collaboration with the Naval Research Laboratory for use on the ESA's Infrared Space Observatory, have shown them to be ten times better than previously available receivers.

NASA's space technology program was developing technologies for a high-efficiency, low-power travelling-wave tube amplifier to transmit all of the data from the Cassini mission from Saturn back to Earth. During 1992, engineers baselined this technology to fly on Cassini. The new amplifier used technology that made it possible to increase output power and efficiency and to recover energy being used for data transmission for reuse. Such advances will enable Cassini to send greater volumes of information back to Earth with low distortion and less energy than currently used, enhancing scientific returns.

Also, in the separate area of aerothermodynamics, NASA engineers have used computer simulation to plan how to "aero-brake" the Magellan spacecraft so as to move it into a lower, more circular orbit around Venus, thereby enhancing the resolution of its mapper with little use of the minimal on-board fuel. Mission planners were still evaluating this plan as the year ended.

And in support of future astronomical missions, NASA's space science technology program completed low background tests for a high-tech imaging array. This technology will directly enhance scientific returns through a large format that allows simultaneous imaging of four times as much area as the current state-of-the-art technology. Also, the program demonstrated a simple control algorithm that can reduce by 2,000 times the vibrations of current flight coolers for sensitive scientific instruments. This technology will improve instrument resolution and simplify spacecraft design necessary to deal with vibrations for future missions.

Because research in a laboratory environment on Earth cannot always guarantee the success of a technology in space, NASA created the **Space Flight Experiments** program. It provides industry, universities, and

NASA the opportunity to validate technologies in the space environment. In the past year, the program launched the Environmental Verification Experiments for the Explorer Platform aboard a Delta II vehicle. This experiment measured spacecraft contamination caused by outgassing in combination with the effects of radiation and atomic oxygen. Results should contribute to better spacecraft design in the future.

NIST was assisting the Johns Hopkins University Applied Physics Laboratory in a separate project developing and calibrating vacuum instruments and techniques used to determine outgassing rates from space materials and satellite assemblies. Outgassed materials could obscure optical images and cause catastrophic discharges in electronic assemblies, among other problems. Prevention and evaluation of these phenomena required quantitative measures of outgassed characteristics, NIST has evaluated instrumentation, developed a new primary standard for water vapor, and calibrated both transfer standards and satellite instrumentation to be used for contamination studies.

Scientists, the majority of whom were principal investigators on NASA space flight experiments, used synchrotron radiation at the NIST Synchrotron Ultraviolet Radiation Facility as an absolute standard of spectral irradiance to calibrate spectrometer sensitivity over a wide range of wavelengths. NIST was also working with the Fault Tolerant Power Technology Group at NASA's Lewis Research Center. NIST has developed fiber-optic current and voltage sensors for power measurements on both aircraft and spacecraft with 20 KHz AC power systems. NIST has delivered two fiber-optic current and two fiber-optic voltage sensors with high stability over a range of temperatures and acceleration levels.

NIST completed research for the Air Force Materials Laboratory on the use of composite materials containing solid lubricants in components of space satellites. The goal of the project was to develop a fundamental understanding of the tribology of self-lubricating composites and to study materials for actual systems. A final report to the Air Force made recommendations on candidate materials (both metal- and ceramic-matrix composites) and on deposited solid lubricant films for new designs of bearings and other moving mechanical systems.

Space Station Freedom

During 1992, the strategic planning process for use of Space Station Freedom (SSF) began. This established plans for research on Freedom for a 5-year planning horizon. For this first cycle, NASA and Canada each developed preliminary partner utilization plans that defined payloads to be flown and operated on Freedom from the delivery of the U.S. Laboratory Module at the end of 1996 through 1997. ESA and Japan participated in the strategic planning process but will not provide their plans for launch of their laboratories until 1993. The first SSF utilization conference occurred in Huntsville, AL, August 3-6. There, NASA presented plans and opportunities for research on Freedom. At the conference, NASA released both an SSF user's guide developed for prospective researchers and the first SSF brochure, "Gateway to the Future," describing its utilization plans.

Japan's Science and Technology Agency and its National Space Development Agency together conducted a successful preliminary design review and initial safety review of the Japanese Pressurized Module and Exposed Facility in July of 1992. The Canadian Space Agency (CSA) has made progress toward the development of the Mobile Servicing System, its contribution to the Space Station. In FY 1992, CSA also conducted numerous design reviews. ESA completed a requirements review of the Attached Pressurized Module System in the summer of 1992, and NASA reached agreement with the Italian Space Agency on Italian-provided Mini-Pressurized Logistics Modules for use on Space Station, signing a memorandum of understanding on December 6, 1991.

At the same time, Freedom program participants have been busy producing thousands of detailed engineering design drawings, from which SSF flight hardware will be manufactured. The program has also been busy performing the preliminary design tasks necessary to expand the Space Station design from the human-tended capability configuration to the permanently crewed capability configuration. This effort continued to involve systems architecture definition through engineering analyses and development test programs.

Thus, FY 1992 included significant testing and development milestones. Engineers constructed many test articles–such as the crew restraints to keep astronauts anchored while working in the weightlessness of space, which Space Shuttle Columbia tested during its June-July mission–to evaluate design integrity and hardware functionality. To accommodate design changes resulting from the Freedom restructuring during the fall of 1990, a "crew-tended capability phase" preliminary design review took place in November 1991. It added substantial technical detail to the baseline and reaffirmed the viability of the current design. There were also preliminary design reviews for the laboratory, node, and cupola during FY 1992. Program engineers completed the first article configuration inspection of the data management system software as well as extensive developmental testing. The Lewis Research Center developed test beds for both the photovoltaic power and the power and power management distribution systems in order to accommodate various model development and qualification tests.

As the year ended, the SSF program was outfitting facilities and developing mission planning and user interfaces for operations/utilization capability. The prime contractors for SSF, as well as astronauts and SSF users, were involved in planning and developing requirements to assist the design, development, and operation of the SSF. The Space Shuttle plays an important role in supporting the development of the SSF operations concepts. Two Shuttle missions this year successfully tested SSF equipment and operations concepts. In April, a flight experiment for "equipment translation aide/extravehicular activity development" flew aboard the Shuttle Atlantis. This tested several concepts for facilitating the mobility of crew members across the exterior of the SSF during extravehicular activities. In August, the "station heat pipe advanced radiator element" flight experiment II flew aboard Atlantis to test an advanced-technology, erectable heat pipe radiator that could reduce the weight of large, high-temperature space radiators by half.

As related in part above, the Space Shuttle has also performed missions involving materials and life sciences that will affect how research is performed aboard SSF. (See coverage above of IML-1, USML-1, and Spacelab J and the treatment in last year's report of Space Life Sciences-1.) What is more, successes like the Long Duration Exposure Facility, with its 5 1/2-year mission (April 1984-January 1990) to test advanced materials for prolonged space exposure, have increased NASA's options to build better, longer-lasting spacecraft. In FY 1992, NASA conducted simulation studies of the benefits that active damping, a process for controlling vibrations, can provide to the Shuttle's Remote Manipulator System (RMS). To date, six astronauts have trained with the technique and indicated significant improvements in the RMS's performance that can be applied to SSF assembly operations.

Energy

The United States has successfully used 37 **Radioisotope Thermoelectric Generators** (RTGs) on over 20 spacecraft launches covering a variety of different space applications. An RTG is a device without moving parts that directly converts the heat from the decay of radioisotope Plutonium-238 (Pu-238) to electricity. Research and development has increased the conversion efficiencies of radioisotope power systems from less than 5 percent to almost 7 percent, which increases the power output or reduces the weight of the power supply–both critical design factors. A new model RTG with a more efficient fuel design called the General Purpose Heat Source (GPHS) RTG is the latest in a series of nuclear power sources developed for space applications by the Department of Energy (DoE).

DoE program activities in FY 1992 focused on planning and restart activities for the production of both GPHS components and GPHS-RTG thermoelectric converters, in order to be prepared to meet the anticipated NASA GPHS-RTG power system requirements for the Cassini mission to Saturn, scheduled for 1997. DoE's restart of GPHS component production and assembly facilities has made significant progress. Oak Ridge, TN, has fabricated clad vent sets for use at Los Alamos National Laboratory in fuel-clad weld development, product characterization programs, and pre-production operations. Start-up activities for fuel processing at the Savannah River Plant, SC; fuel-clad fabrication at Los Alamos; and RTG assembly and test at the Mound Plant of EG&G Mound Applied Technologies in Miamisburg, OH, have been extensively reviewed, with approvals obtained for operations. The prime system contractor's principal efforts have continued to focus on reestablishing production capability for thermoelectric unicouples. Production of test hardware for unicouple qualification began in 1992. Other activities included the continued development of a new RTG shipping package and the initiation of the development, design, and qualification of a 1-kilowatt thermal shipping package suitable for fuel, fuel clads, and GPHS modules. The contractor produced engineering and qualification test hardware for the respective programs.

In FY 1992, the modular radioisotope thermoelectric generator program (MOD-RTG) focused on the design, development, manufacture, and test of improved multicouples both in an electrically-heated engineering, 8-multicouple test module configuration and in individual multicouple test stations. An 8-multicouple, high-purity test module exhibited normal performance through 5,040 hours under simulated service conditions. An electrical heater failure interrupted the test in September, however. A second, high priority test module continued operating after 2,050 hours of successful performance. Tests of individual multicouples were continuing after the successful completion of approximately 11,000 hours for 4 units and 2,700 for 4 others, through the end of FY 1992. The MOD-RTG design with its capability to tailor power to meet specific mission requirements should provide a significant advance in RTG specific power (watts/kilogram) and in improved efficiency for use in NASA's lunar, Martian, and solar system exploration as well as in DoD missions during the next decade.

The DoE also continued its work on the **SP-100 Space Reactor Program**, which sought the development of a power system for civil and defense missions using a nuclear reactor capable of providing electric power in the range of tens to hundreds of kilowatts. In this area, an updated SP-100 Generic Flight System (GFS) design has demonstrated that a 100-kilowatt system with a mass of no more than 4,600 kilograms is achievable. Researchers have identified a thaw concept allowing the reactor to restart after shutdown using an auxiliary cooling loop. Engineers have completed development of fabrication techniques for the reactor, fuel, and fuel pins. They have tested the fuel pins to the equivalent of 7 years of operation at full power. The system contractor was developing the final steps to assemble the thermoelectric cells that will produce 25 times the electric power available from the thermoelectric cells used in the 1989 Galileo mission. Two materials test loops containing lithium at 1,350 degrees Kelvin have successfully demonstrated the welding and fabrication techniques for high-temperature, refractory niobium alloys. One operated for over 3,000 hours and the other for 1,000 hours. Engineers have completed tests for void and thaw characterization of lithium. Thaw and extrusion tests have confirmed that the reactor design accommodates lithium thaw with minimal stress on reactor components. Engineers have also made significant progress in developing the self-actuating thermoelectric electromagnetic pumps that will transport the lithium from the reactor to the power conversion system. They have demonstrated techniques for explosively forming the pump ducts and bonding thermoelectric cells to the ducts.

Progress has also been made on technology for an in-core Thermionic **Space Reactor**. In 1992 DoE awarded two contracts and work began under the Thermionic Space Nuclear Power System Design and Technology Demonstration Program. Its goal is to provide a baseline thermionic nuclear space system point design at 40 kilowatts electric, scalable over 5 to 40 kilowatts. One of the contracts will develop a multicell Thermionic Fuel Element (TFE) design, while the other will develop a single-cell TFE design based primarily on Russian technology. The TFE Verification Program began in 1986 to resolve feasibility issues surrounding long-life, high-power (2 megawatts) thermionic space reactors. It has expanded the data base on performance and lifetime of TFEs and has demonstrated a TFE lifetime of about 18 months. To date, the program has identified no physical mechanisms that could limit lifetimes to less than 2 years. In response to changing DoD requirements (such as shorter lifetimes and lower power), the DoE reorganized the program late in FY 1992 to support the Thermionic System Design and Technology Demonstration Program. The TFE Verification Program will be phased out by the end of FY 1994, at which time technologies required by each 40 kilowatt system design will be demonstrated through the system design contractors' efforts.

In response to the Space Exploration Initiative announced in 1989, DoE, in cooperation with NASA, has worked on technology for **Nuclear Propulsion**, which promises to reduce costs, decrease the size of spacecraft, and provide shorter piloted planetary missions. Several key DoE activities in the fuels and materials areas began in FY 1992. Researchers obtained the melting points and vaporization constants for very high temperature carbide fuel forms. They made progress in using a new cryochemical process to fabricate a variety of fuel forms and in the development of a new organo-metallic coating process to resist attack by the hydrogen propellant at very high temperatures. There has also been progress in the fabrication of all the leading fuel types under consideration in the program. In addition, reestablishment of the previous fuels-making capabilities in the former Rover/NERVA program has begun.

DoE has also cooperated with NASA in defining reactor/engine concepts that could be used in the NASA missions. In addition to U.S. concepts, evaluation has begun of Russian fuel forms and testing capabilities. The Russians had continued development of nuclear rocket fuels after the U.S. discontinued that work in the 1970s. The results of the Russian efforts in advanced nuclear propulsion fuels and their testing may be useful to the U.S. The DoE also participated with NASA and the DoD in planning for future activities in nuclear propulsion. The capability of DoE laboratories was an important national asset in this regard.

The DoD's Strategic Defense Initiative Organization (SDIO) has also worked to bring about the transfer of former Soviet space nuclear power technology to the U.S. with the acquisition of the technology from the TOPAZ II space nuclear reactor. Also acquired from the Commonwealth of Independent States were electric thrusters based on the Hall effect principle. The University of New Mexico was integrating these technologies into a flight experiment using the TOPAZ II to power electric thrusters for raising spacecraft into orbit. This experiment will study the physics of the interaction with the space environment and the spacecraft of plasmas generated by electric thrusters. NASA will benefit from the fundamental knowledge acquired as well as the creation of a space-qualified nuclear electric propulsion/power system.

Meanwhile, NASA's space technology program made significant progress towards completing nuclear and energy conversion technologies to provide lightweight **Space Power** systems. It validated the design of the primary cooling pump for a reactor system. In the area of power conversion, it made improvements in thermoelectric materials that could reduce the weight of a power system by 10 to 15 percent. In addition, it fabricated a high-performance Stirling cycle dynamic power conversion system. This could increase the electrical power produced by a nuclear reactor by a factor of five while only doubling the weight. In particular, engineers fabricated a critical component of the system–a superalloy heater head. Providing heat from the reactor to the energy conversion system, this technology demonstrated a 50-percent performance margin over required power levels.

Safety and Mission Quality

The complex technical and scientific nature of NASA's mission required not only careful planning but frequent troubleshooting. Despite occasional operational flaws such as failures in-orbit, problems with ground hardware, and software anomalies, several NASA robotic spacecraft have continued successfully to carry out their missions. Examples have included the Hubble Space Telescope (HST), the Compton Gamma Ray Observatory (GRO), and Galileo. The Space Shuttle recovery and relaunch of the INTELSAT-VI satellite provided another instance of real-time problem solving. Understanding and resolving in-orbit spacecraft problems accomplished two goals: continued and often enhanced mission performance, and setting forth lessons learned that were applicable to current and future spacecraft design and operations.

To these ends, a coalition of NASA, contractor, and academic technical organizations concerned with safety, reliability, and quality assurance have developed tools and methodologies to track down the causes of failures and anomalies affecting spacecraft and ground stations and then to determine the most appropriate ways to resolve them. As a result of such efforts, for example, the HST continues to produce a wealth of valuable and often unexpected astronomical data (as related above), often in combination with GRO and other scientific spacecraft. The problem resolution activities associated with the HST on-board main computer's recent partial loss of memory best illustrate this process.

During the 15 days from July 19 to August 2, 1992, the main computer memory #4 failed to operate properly, so Mission Operations at Goddard Space Flight Center (GSFC) took it off-line and replaced it with unit #5. Previously, on May 2, 1991, computer memory #3 had failed and was similarly taken off-line and replaced with unit #6. The memory #3 Failure Review Board at GSFC isolated the failure mechanism to the memory module bit-driver electronics. These two failures left four of the six existing memory units operating, and the computer continued to exercise proper control of the HST. On August 4, 1992, a Failure Review Board began to isolate the cause of the most recent memory #4 failure and to develop recommendations for recovery. Use of modern fault tree analyses, unique in-orbit and ground engineering tests, and probabilistic risk assessments helped in the process. With them, engineers were able to isolate the failure mechanism to the power supply in the failed memory unit.

As a result of this process, the December 1993 mission to service the HST and install instruments that will correct the errors in the primary mirror will also be able to repair its computer. The review board process has also provided a lesson learned that will avoid a repeat of the computer failures. This sort of "do it right" philosophy achieves better, faster, and cheaper solutions to problems on the ground and in flight without compromising safety.

In a different area, NIST has developed a theoretical model capable of predicting pyrolysis and smoldering of cellulosic material in a microgravity environment using experimentally measured thermal degradation kinetics in a normal gravity. NIST researchers have extended the model to include ignition and subsequent flame spread in three dimensions by incorporating gas phase oxidation chemistry to examine the fire safety in spacecraft. NIST has examined NASA's material flammability screening test by comparing it with a set of NIST flammability characterization test methods, using selected NASA materials.

Other Space Technology

Besides developing technologies for specific applications in space, NASA engaged in a great deal of basic research and development. Universities throughout the country play a key role in this basic research and technology program. In April 1988, NASA announced the competitive selection of nine **University Space Engineering Research Centers**. They foster creative and innovative concepts for future space systems while conducting focused research in one or more of the traditional space engineering disciplines and in cross-disciplinary combinations. This enhances engineering education by directly involving students in space engineering research tied to NASA's future mission needs. In the past year, students and faculty at the University of Michigan made considerable progress towards developing devices that can measure the chemical makeup of the upper atmosphere. This research will help NASA both to study and to understand global change issues such as ozone depletion. (See also below under Aeronautical Activities, Technological Developments, entries dealing with basic research and computational methods.)

The **Strategic Defense Initiative Organization** (SDIO) also engaged during FY 1992 in a wide-ranging research program. It continued work, for example, on the development of miniaturized and accurate subsystems for interceptors. It has reduced the weight of an inertial guidance system to about 900 grams, with the goal being to reduce it to less than 500 grams. Other achievements in this area included a tiny divert rocket motor using new, high-temperature material that reduced the weight of the interceptors by 30 percent and a new seeker telescope with a 75 percent weight reduction that can be built at greatly reduced cost. In the area of sensors and radars, SDIO has developed a star tracker camera with a wide field of view, using a silicon-charged, coupled device with a weight of less than a quarter of a kilogram and an ultraviolet/visible camera of the same material weighing less than half a kilogram. With respect to phenomenology, among the many achievements of SDIO in the past year were new, large-format missile warning infrared detectors using indium antimonide to track missiles at unprecedented distances with very clear imaging. Finally, in the field of airborne computer technology, among many achievements in FY 1992, SDIO has successfully tested silicon carbide for computer memory, with the advantage that information is retained when the power is off. This new semiconductor material provides a drastic reduction in the size of spaceborne computers and in the electric power required to operate them.

The **Defense Nuclear Agency** (DNA) continued in FY 1992 to develop technology allowing space systems' survivability in hostile environments. The agency continued development of a survivable, 1-million-bit, static random access memory plus hardening and producibility technologies for the high density integration method of electronic chip packaging to meet the increased requirements for on-board data processing on satellites, with reduced weight and volume. These new technologies will have increased fault tolerance and be able to survive the environments present in the Earth's trapped radiation belts, as well as those due to solar flares and cosmic radiation. The hardened optics program has significantly advanced the state of the art in hardened optical components technology, critical to space-based surveillance and optical communications functions, as well. For example, DNA's hardened optics program has developed reflective coatings for space optics that are resistant to atomic oxygen, charged particles, and ultraviolet radiation; they are also hardened against x-rays from a nuclear burst.

The **NASA** space technology program also recently developed the first comprehensive engineering code capable of conducting shielding analyses of high-energy space radiation, covering single nucleons through heavy elements such as iron. More than 100 times faster than conventional methods of analysis, it will help mission planners to predict the effectiveness of spacecraft and planetary habitat shielding against solar flares and cosmic radiation. It is expected to become the industry standard.

Space Communications

Communications Satellites

An Ariane 44L launch vehicle successfully launched the International Telecommunications Satellite Organization (INTELSAT VI [F-1]) satellite, its fifth and last VI-series spacecraft, on October 29, 1991, from Kourou, French Guiana. INTELSAT, a consortium established in 1964 and consisting (by the end of 1992) of 124 countries, managed and operated the global communications satellite system of which INTELSAT VI was a part. Like its predecessors, the new satellite had 38 C-band and 10 Ku-band transponders that could simultaneously carry as many as 120,000 telephone calls and 3 color television channels during its planned 13-year lifetime.

On May 14, 1992, the INTELSAT VI (F-3) satellite's replacement booster motor, attached to the 4 1/2-ton spacecraft the previous night by the crew of NASA's Space Shuttle Endeavour, fired successfully, dispatching the F-3 into super-synchronous transfer orbit. INTELSAT's telemetry, tracking, and command station in Gandoul, Senegal, commanded the motor to fire after receiving approval from Mission Control at the INTELSAT headquarters in Washington, D.C. INTELSAT subsequently separated from the satellite the replacement booster and the capture bar the Shuttle crew had attached. Then, on May 21, 1992, INTELSAT placed the satellite into geosynchronous orbit, completing the deployment of the solar drum and antenna array on the F-3 (also known as the 603) on May 23. The newly positioned satellite was expected to have an 11.5-year lifetime, becoming the fifth VI-series spacecraft in the INTELSAT network. Positioned over the Atlantic Ocean, it joined two sister satellites there, while two were then located over the Indian Ocean. Thirteen INTELSAT V/V-A satellites completed its network, providing communications to countries around the world.

The following month, on June 9, 1992 (local time), INTELSAT's highest powered satellite to date, the **INTELSAT-K**, was launched on an Atlas IIA from Cape Canaveral AFS, FL. Built by General Electric and destined for a position over the Atlantic Ocean, the new satellite would provide such services as satellite news gathering, television and radio transmission to the eastern half of North America, all of Europe as far east as Moscow, and the major urban areas of South America. It is INTELSAT's first satellite to operate in the K-band (11-12/14 gigahertz) and brought to 19 the total number of satellites being operated by INTELSAT.

Meanwhile, on December 16, 1991, the **INMARSAT 2** (F-3) satellite, the third of the International Maritime Satellite Organization's (INMARSAT's) new generation of global, commercial, and mobile communications satellites, was launched aboard an Ariane 4 rocket from Kourou, French Guiana. INMARSAT is a London-based international cooperative founded in 1979. With 64 member nations at the end of 1991, the organization provided telephone, facsimile, telex, electronic mail, data and position reporting, and fleet management services, including distress and safety communications, for land mobile, aeronautical, and maritime customers. The new F-3 satellite entered into service on January 19, 1992, over the Pacific Ocean, where it provided coverage for the western United States, eastern Asia, Australia, New Zealand, and most of the Pacific Ocean.

An Ariane 4 rocket also launched the fourth and final INMARSAT 2 satellite (F-4) from Kourou on April 15, 1992. It completed the organization's second generation of satellites and was scheduled to become operational in May 1992 over the western Atlantic Ocean Region. In addition, F-1 provided service over the Indian Ocean Region, while F-2 served the eastern Atlantic Ocean Region. As the year ended, a contractor was constructing INMARSAT's third generation of satellites, which were scheduled for launch in 1994-95.

There were three new **Domestic, Fixed Communications Satellites** launched for the United States during FY 1992. All of them were commercial replacement satellites launched into locations of satellites nearing the ends of their fuel lives. These satellites will provide domestic service into the next decade and will offer users a wide range of services including video, high-speed data, private network, and audio services. An Atlas I launched Galaxy 5W on March 13, 1992, from Cape Canaveral. A Delta II launched Satcom C4 from Cape Canaveral on August 31, 1992, and on September 10, 1992, an Ariane 4 launched Satcom C3 from Kourou, French Guiana. This launch raised to 33 the total number of domestic fixed satellites in orbit between 69 and 139 degrees West Longitude on the geostationary orbital arc.

For the military, the **Defense Satellite Communications System** (DSCS) continued to serve as the long-haul, high capacity communications system supporting the worldwide command and control of the U.S. Armed Forces and other Government agencies. The DSCS program successfully launched two new DSCS III satellites on February 10 and July 2, 1992. These launches marked the start of a replenishment program for the DSCS constellation, which had experienced launch setbacks from the Space Shuttle Challenger explosion in 1986. Eight more DSCS IIIs were scheduled for launch between FY 1993 and FY 1999. The two 1992 launches also marked the first use of a new launch booster, the Atlas II, and an inertial upper stage as well as significant modifications to the satellites. One of these new satellites had already begun handling operational traffic by the end of the year, and the second was scheduled for cutover in early FY 1993. The cutover of the first new DSCS III satellite permitted a substantial reconfiguration of the constellation. A DSCS II in the West Pacific was replaced with a DSCS III, and a newer DSCS II was moved into the Indian Ocean, thereby improving service to the DSCS customers. The result at the end of FY 1992 was four mission-supporting, fully-capable DSCS IIIs located in the East Atlantic, West Atlantic, East Pacific, and West Pacific areas, respectively, plus the DSCS II in the Indian Ocean area. In addition, the residual on-orbit satellites having partial capability consisted of three DSCS IIs launched before 1983 and a DSCS III launched late in 1982.

The Mean Mission Duration (MMD) of the DSCS II increased to 5 years in the final acquisition phase, with some of these satellites continuing to provide service beyond their MMD. The DSCS III had an MMD of 7 years, and even though these satellites were far more complex than the DSCS IIs, they were expected to achieve their MMD. The DSCS control segment provided semi-automated management of DSCS resources to maintain the satellite communications network in alignment with the needs of the operational commanders. As of April 29, 1992, the Army Space Command completed consolidation of all DSCS operations centers under its auspices. Based upon lessons learned from Desert Shield/Desert Storm, the DSCS program was implementing a more responsive and robust super high frequency tactical control capability. During FY 1992, DSCS space and ground resources provided support of a wide variety of contingencies and other requirements, including the President's Pacific Rim trip, Hurricane Andrew, Provide Comfort, and Somalian Relief efforts.

Still in development was **Milstar**, programmed to be the cornerstone of the DoD's Military Satellite Communications architecture. When operational, it will be a multichannel, Extremely High Frequency (EHF)/Ultra High Frequency (UHF) satellite communications system to provide survivable, enduring, jam-resistant, and secure voice and data communications for the armed forces and other users. The Air Force was the lead service for procuring Milstar satellites, a dispersed mission control network, airborne terminals, and ground command post terminals. The Army and Navy also had programs for terminal development and procurement. After an earlier restructuring in FY 1991, the DoD again restructured the Milstar program in FY 1992 to increase life-cycle savings and be responsive to a Joint Requirement Oversight Council Memorandum directing an exploration of less costly alternatives for polar connectivity. The first Milstar satellite was on track at the end of FY 1992 for delivery in December 1992, with satellites 2 and 3 at 90 and 60 percent completion, respectively.

Meanwhile, the **Fleet Satellite Communications** (FLTSATCOM) System provided worldwide Navy and DoD UHF satellite communications through a constellation of four Navy-owned FLTSAT and three leased satellites positioned in geosynchronous orbit at four locations around the Earth. The two newest FLTSAT spacecraft carried an EHF package for testing Milstar terminals. To replace this aging constellation, DoD has authorized the production of nine UHF Follow-on (UFO) satellites, with satellites four through nine incorporating an EHF communications capability. The Navy expected the launch of the first UFO satellite in early FY 1993.

During FY 1992, DARPA successfully transitioned the **Multiple Access Communications Satellite** (MACSAT) store-and-forward satellite system to the Naval Space Command. DARPA had launched two MACSATs aboard a Scout booster in May 1990, and the armed services had used them in exercises as well as Operations Desert Shield and Desert Storm. The MACSATs provided global relay of messages, data, facsimile, and graphics services to small, human-portable UHF terminals.

A Pegasus had launched seven **Microsats** in July 1991, but it had placed them into an improper but usable orbit. These small satellites (about 19 by 48 centimeters in height and diameter, 22 kilograms in weight) supported military exercises, including Operation Balikatan that provided disaster relief to the Philippines in the aftermath of the Mount Pinatubo eruption in June of 1991. However, in January 1992 the support ceased when the orbiting constellation re-entered the Earth's atmosphere. Until then, they had provided radio relay service in the UHF band, as well as limited-capacity store-and-forward capability.

Space Network

NASA's Space Network continued to provide tracking and communications capabilities to a variety of Earth-orbital missions that are dependent upon these capabilities for mission success. The **Tracking and Data Relay Satellite (TDRS) System (TDRSS)** is the Network's space-based system providing communications plus command and control services to low-Earth-orbiting spacecraft. In FY 1992 the network provided communications services to three new customers: the Upper Atmosphere Research Satellite, launched September 12, 1991; the Extreme Ultraviolet Explorer (EUVE), launched June 7, 1992; and the Ocean Topography Experiment (TOPEX), launched on August 10, 1992. These join other notable missions such as the Hubble Space Telescope (HST), the Compton Gamma Ray Observatory (GRO), all Space Shuttle flights, and others that are TDRS-dependent. The growth in number of Earth-orbiting satellites requiring TDRS services since FY 1989 has resulted in an increase of over 100 percent to more than 15,000 hours of service provided in FY 1992.

During FY 1992, NASA's Goddard Space Flight Center developed phase I of the **TDRSS Onboard Navigation System** (TONS) to operate as a flight experiment on NASA's Explorer Platform/EUVE, launched June 7, 1992. The results to date have been excellent. NASA's Office of Space Communications (OSC) sponsored TONS to provide cost-effective, highly accurate, transfer for customer spacecraft using NASA's Space Network.

On June 8, 1990, NASA signed a long-term lease with Columbia Communications for **C-band Transponder** use on the TDRS. This lease covered 24 transponders aboard the TDRS for 6 years after the 1st of January, 1992, at an annual recovery to the Government of over $10 million per year.

Communications and Data Systems

NASA's OSC redesignated the **Packet Data Processor** facility, initially designed to meet the unique requirements of the GRO, as a multi-satellite facility to enable the processing of scientific data received from NASA's next generation of Earth-orbiting spacecraft. The redesigned facility will use packet data standards developed by the international Consultative Committee for Space Data Systems (CCSDS), which is chaired by an OSC staff member. The design as of the end of FY 1992 was based on the use of power workstations (instead of large central computers) and Very Large Scale Integration microelectronics that provide high speed processing not achievable with software solutions. This technology involved use of single chips that could contain tens of thousands of individual circuits, permitting extremely fast operations because of the short electrical transmission paths on the single chip.

The OSC continued to lead initiatives seeking efficiencies resulting from adopting international space data systems standards. During FY 1992, OSC achieved agreement within NASA that most new missions scheduled for launch after 1993 will employ CCSDS-compatible telemetry systems. Use of common data systems standards will reduce or eliminate the need for mission-unique hardware, software, and operating procedures, thus greatly improving the efficiency of mission operations. International partnerships in space activities also benefit from adoption of CCSDS standards by simplifying the sharing of operations functions and data among partners.

Another segment of communications and data systems consists of spacecraft control centers, which are required to generate and transmit commands to spacecraft to direct the operations of spacecraft and their payloads. OSC evolved to a new **Transportable Payload Operations Control Center** architecture, which used high power workstations instead of large central computers to provide service faster, better, and less expensively. The Solar Anomalous and Magnetospheric Particle Explorer, launched in July 1992, was the first spacecraft to use the new, multi-satellite facility.

Ground Network

NASA's Ground Network facilities provided spacecraft communications to the Space Shuttle; to planetary spacecraft such as Magellan, which continued its successful mapping of the surface of Venus; and to Earth-orbiting spacecraft performing a variety of Earth observing missions. These communications permit controllers to navigate the spacecraft from the ground and configure them for scientific observations; they also enable scientific data to be received on the ground. During FY 1992, the Ground Network facilities also provided communication services during the launch, flight, and recovery of high-altitude balloons and rockets employed for research in such scientific disciplines as geophysics, astrophysics, and astronomy.

A further use of the ground networks, which employ some of the largest antennas in the world, was to map the surface of planetary objects. During 1992, scientists were successful in using the Deep Space Network Radar to observe Jupiter's moon Io, Saturn's rings and its moon Titan. Observations of Titan will provide critical information for planning the Cassini mission. The Deep Space Network antennas also served as elements of Very Long Baseline Interferometry experiments to make detailed maps of astrophysical sources such as suspected black holes within our galaxy.

Aeronautical Activities

Technological Developments

Within the Federal Government, both the DoD and NASA engaged in the development of new and improved technologies within the aeronautical field. An important example of these activities was the **Pilot's Associate Program.** This applied many of the technologies being developed under the Strategic Computing Program of the Defense Advanced Research Project Agency (DARPA) and the U.S. Air Force to assist pilots in making decisions in potential combat situations. The program consisted of a knowledge-based system to be embedded in future avionics systems both for use on new aircraft and retrofit to existing aircraft. The specific technologies employed in the program included artificial intelligence, automated planning, advanced pilot-machine interface, and the supporting computer technology necessary for their implementation. Technological advances employed in the program would provide the pilot of a single-seat fighter aircraft assistance in the highly dynamic and demanding environment of aerial warfare. The program culminated in FY 1992 with a successful demonstration in an advanced flight simulator representative of the fighter aircraft projected for the mid-1990s. The applications of this technology were numerous, with efforts planned or underway at the end of FY 1992 to exploit this capability on Army rotorcraft, the Special Operations Forces Combat Talon 1, the Navy AX program, and several commercial applications.

Another important research and development effort involved the **National Aero-Space Plane** (NASP), a Presidentially-directed, joint DoD-NASA program. Its objective was to develop and validate technologies for an entirely new generation of aerospace vehicles, some of which will be single-stage-to-orbit space planes that fly at hypersonic speeds (greater than Mach 5) to provide flexible, efficient space-launch capability with horizontal takeoffs and landings on runways. Another capability will be long-range hypersonic cruise within the atmosphere. The two agencies plan to integrate the requisite technologies into the design and fabrication of an experimental, crewed research aircraft, the X-30, for flight test and demonstration. Key features expected to be included were supersonic-combustion ramjets (scramjets) fueled with hydrogen carried on board as slush, a liquid-solid mixture; rocket power to provide thrust for the final climb to orbital insertion; light-weight, titanium-aluminide alloy, capable of retaining high strength at temperatures up to 1,500 degrees Fahrenheit for the main structure; and protection for the hottest segments of the engine and airframe through "active cooling" using the super-cold fuel as a heat sink. The next generation vehicle was expected to provide global, unrefueled operation to any point on Earth in less than two hours and routine as well as flexible, "on demand" access to space.

The NASP program, through its contractor and Government research centers and test facilities, has fabricated component hardware, manufactured materials, and performed aerodynamic, mechanical, and thermal ground tests. The list of major technological achievements in FY 1992 includes: successful test of a one-seventh-scale set of three NASP inlets at Mach 18; test of a large-scale, titanium-matrix composite fuselage section with an integrated carbon-epoxy cryogenic fuel tank (filled with liquid hydrogen at cryogenic temperature) heated on the outside to 1,300 degrees Fahrenheit and stressed with external loads simulating Mach 16 flight conditions; completion of various structural-article tests (including that of a titanium-matrix composite panel through 150 thermal life cycles, an acoustics-loads test of a carbon-carbon panel for an engine nozzle surface, and a mechanical/thermal-loads test of a carbon-carbon wing box structure heated to 1,915 degrees Fahrenheit); test of the low-speed engine design concept and the high-speed, subscale integrated engine (inlet, combustor, and nozzle); both production of a high ratio of solid-to-liquid fuel and evaluation of fuel transfer characteristics for slush hydrogen; successful endurance by hydrogen-cooled structures simulating an engine-inlet lip of the extreme heating levels of shock impingement at Mach 15–simulated with high-powered lasers; and breakthroughs in materials processing that facilitate the production of materials such as Beta 21S, a titanium alloy that can be strengthened with silicon-carbide fibers to form a high-temperature metallic "composite." Spinoffs of NASP technology that were moving into U.S. industry included materials for automobile engines, computer systems, heart-valve replacements, and piping for deeper oil wells. NASP computer-science advances were applicable to a wide variety of vehicle and engine designs.

The joint **X-31A Enhanced Fighter Maneuverability (EFM)** program to develop an aircraft with increased agility and maneuverability was a cooperative effort between Germany and a DARPA-U.S. Navy partnership. In February NASA and the U.S. Air Force became active program participants in an International Test Organization (ITO) activated at NASA's Dryden Flight Research Facility. It included Rockwell and Messerschmitt-Bolkow-Blohm in addition to the parties already mentioned. Before that, initial flight tests of the aircraft had occurred at Rockwell's Palmdale facility, but then the aircraft moved to Dryden to expand the flight envelope. The X-31A has demonstrated increased maximum turn rates and a decreased turning radius, resulting in an ability to point its nose rapidly. One program objective is to improve combat effectiveness significantly through an ability to maneuver up to 70 degrees angle of attack

(AOA), whereas current aircraft lose maneuverability and can stall at about 30 degrees AOA.

As the year ended, the ITO was rapidly approaching the most challenging post-stall flight testing. It had already conducted 102 flights in the conventional flight envelope, achieving a speed of Mach 0.9 at 40,000 feet (12,192 meters) while subjecting the pilot to a force of 7.0 g. Other FY 1992 achievements included a post-stall flight to 50 degrees AOA on November 19, 1991; a post-stall flight to 70 degrees AOA and a full-stick velocity vector roll to the same AOA, both on September 18, 1992. Throughout the envelope, the aircraft exhibited pilot-friendly handling. The final flight test phase will occur in FY 1993 to test the tactical utility of the EFM technologies.

The **F/A-18E/F** will constitute the second major upgrade of the F/A-18 aircraft. The F/A-18E (single seat) and the F/A-18F (two seats) will be high-performance, twin-engine, mid-wing, multi-mission tactical aircraft. Their purpose will be primarily to meet current Navy and Marine Corps fighter escort and interdiction mission requirements and to maintain additional F/A-18 fleet air defense and close air support roles. Enhancements will include the increased range and improved carrier suitability required for the F/A-18 to continue its key strike fighter role against the advanced threat of the late 1990s and beyond.

Studies by the U.S. Navy have identified increased mission range, payload flexibility, and aircraft carrier suitability as key requirements. The F/A-18E/F incorporates several changes in structure and airframe systems to improve performance and provide capability for future growth. The center fuselage is lengthened for more fuel volume. The wing and Leading Edge eXtension (LEX) areas were increased to meet wind-over-deck requirements for catapult operations and carrier approaches. Two additional stores stations in the wing provide increased payload and payload flexibility. Uprated General Electric F404 engines (now designated F414) provide increased thrust to support the overall increased size and weight. New avionics bay volume, and the necessary cooling/power capacity will permit incorporation of future upgrades to avionics and weapons.

In May 1992 a Defense Acquisition Board approved the program's entry into the engineering and manufacturing development phase. That will end in FY 2000, providing an expected 42 aircraft through low rate initial production. These aircraft will provide operational testing and the initial planes for squadron "stand-up" plus a gradual phase-in to a full-rate production. Authorization to proceed with full-rate production should occur in FY 2000, the expectation being that subsequent procurement will total 958 aircraft.

Another new aircraft in development by the DoD was the **B-2**, whose primary mission was to enable any theater commander to hold at risk and–if necessary–attack an enemy's warmaking potential. As of the end of the fiscal year, four of the aircraft were undergoing test flights. They had accumulated some 830 hours of testing in a total of 180 sorties. In June, the static test article completed its second lifetime of testing, qualifying the structure for its 10,000-hour lifetime, with only one static test condition left to be completed. Also, in the low observable testing in which the aircraft's performance had been less than predicted in July 1991, results by August 1992 had demonstrated that the B-2 can meet or exceed its specifications, showing that its basic design was sound. Program managers anticipated a decision on the low observable configuration of the aircraft in December 1992. Meanwhile, in January 1992 the President had decided to reduce the size of the B-2 program to 20 operational aircraft with the first one delivered in late 1993.

The **AX** is expected to be a multi-mission aircraft to replace current medium/long-range strike/interdiction aircraft in the Navy and Air Force inventories. It must perform its mission during the day or night, in all weather conditions, at high or low altitude, and on firm land or a carrier. Designed to penetrate advanced, multi-layered, integrated air defense systems, AX will be expected to locate, identify, target, and destroy highly defended surface and airborne targets in the early 21st century. The AX design must optimize carrier suitability, affordability, survivability, strike/anti-submarine warfare capability, and anti-air warfare capability.

Ongoing efforts at the end of the fiscal year included the cost and operational effectiveness analysis of a range of alternatives, supported by a contract exploration among five contractors and definition studies. The program was scheduled for its first milestone review in the spring or summer of 1993. At that point, the DoD will determine whether to begin the demonstration and validation phase of the procurement process.

The DoD completed a highly successful flight test program in FY 1992 using the **X-29 Advanced Technology Demonstrator** as a testbed for the Vortex Flow Control (VFC) program. The Department chose the X-29 with its forward-swept, aeroelastically-tailored composite wings and close coupled canards as the testbed due to its excellent stability and control up to 50 degrees AOA. The 60 flights in the program used a unique high pressure system to exhaust nitrogen rearward over the aircraft nose area from two small nozzles to induce vortex movement and initiate yawing moments. The payoffs of this research included better control at high AOA and reduced-tail or possibly no tail surfaces for future fighter aircraft. Results from this program were being used to implement a VFC system on the F-16 to enhance its combat maneuverability at intermediate to high AOAs.

In a related area, the **Advanced Fighter Technology Integration** (AFTI/F-16) program continued flight testing of advanced technologies in support of aircraft with the air-to-surface attack mission. This Air Force Initiative continued flight tests in FY 1992 of head-steered, forward-looking infrared, helmet-mounted displays; night-vision-goggle-compatible lighting; and multiple, digital-terrain-data-based systems (automatic terrain following, ground collision avoidance, route replanning, and terrain-aided navigation) required for safe day/night, all-weather, low-altitude, combat mission accomplishment. Flight testing of these technologies through FY 1992 gathered data on key system components, including digital terrain-elevation data, a pilot-activated recovery system, the all-terrain collision avoidance system, and a silent attack radar altimeter.

The **Integrated High Performance Turbine Engine Technology** (IHPTET) initiative was a coordinated DoD/NASA/industry effort to provide revolutionary performance and operational improvements for all military engine systems. Its goal was to double turbopropulsion capability and reduce cost with no compromises in propulsion system life, reliability, and maintainability. Some of the IHPTET program's accomplishments in FY 1992 include the in-house testing of an enhanced-flow compressor that demonstrated full-flight capability for subsonic to supersonic applications; structural testing of a metal-matrix composite engine component that reduced its weight by 40 percent; and the fabrication and test of an innovative nozzle actuator featuring advanced ceramics, composites, and optics that provide a high-temperature, low-weight capability. Future efforts will further investigate new materials applications to various engine components, increased operating temperature capabilities for combustors, turbine blade cooling technology, and designs for increasing reliability, durability, and manufacturability.

NASA Subsonic Aircraft Research during FY 1992 focused on developing selected new technologies to ensure the competitiveness of U.S. subsonic aircraft in the world market and enhance the safety and productivity of the nation's airspace. Much of NASA's research focused on reducing drag and improving lift–advances that could lead to significantly better fuel economy in tomorrow's airliners. Coupled with that work were efforts to design quieter and more efficient engines (see below) and to reduce aircraft weight through increased use of composite materials. NASA and the FAA were also working together to enhance safety in the nation's airspace by improving cockpit technology and air traffic control systems (see below).

The high lift research program conducted at NASA's Langley Research Center consisted during FY 1992 of flight tests, using the B-737 Transportation Systems Research Vehicle, wind tunnel testing of a model of the same aircraft in the 14-by-22-foot tunnel, and a computational effort that joined the flight testing and wind tunnel efforts. Flight data collection had ended by September 1992, and engineers had performed computational calculations for correlation. Further wind tunnel tests remained to be completed at the end of the year. The overall thrust of the program was to resolve differences in the flight test and wind tunnel results to determine the Reynold's number effects on the boundary layer development and growth. Researchers will incorporate that information into efficient computer design programs that can be used in producing simpler, more efficient high lift systems. This will result in a more efficient system that is less costly and easier to maintain. Such systems were expected to result in smaller propulsion systems on aircraft and significant reductions in noise in the take-off and landing portions of the flight envelope.

NASA was also engaged in **High-Speed Research**, focused on resolving critical environmental issues and laying the technological foundation for an economical, next-generation supersonic transport expected to be critical to the competitive posture of the American aerospace industry in the next century. During 1992, NASA in cooperation with an international group of world-renowned scientists improved available atmospheric models through the addition of multi-phased chemical effects. Use of the improved models indicated that a fleet of 600 high speed commercial transport aircraft with advanced low-emission engines, flying at speeds up to Mach 2.4, would cause virtually no impact on stratospheric ozone. Laboratory testing of low-emission combustor concepts by NASA at the Lewis Research Center and by private industry increased in 1992, with emission levels better than the program goal of 5 grams of nitrogen oxide per kilogram of fuel.

A second major environmental requirement for any future high speed commercial transport was achieving acceptable airport noise levels. This presented a formidable challenge in view of a requirement to achieve a reduction in noise level of 20 decibels (dB) from the level of the Concorde aircraft. Testing of promising engine noise-reduction concepts, such as the mixer-ejector exhaust nozzle, continued in 1992 to address this requirement while maximizing thrust performance. Wind tunnel tests at the Langley Research Center of advanced aircraft high-lift devices took place in close cooperation with industry. They indicate the potential for an additional 2-6 dB reduction in noise level through advanced operational procedures during takeoff and landing.

While studies have concluded that an economically viable, high speed civil transport is not dependent upon unrestricted supersonic overland flight capability, they also have shown operational flexibility and market size would be considerably enhanced by limited overland corridor operations. As a result, technology that reduces sonic booms is an integral and important element of the program. During 1992, flight testing of several military aircraft generated an extensive data base on atmospheric propagation of sonic booms. Researchers were using this information in conjunction with metrics of human responses to loudness to guide development of alternate aircraft configurations to soften sonic boom without a significant penalty in aerodynamic efficiency.

The newest element of the program, Enabling Propulsion Materials (EPM), began in 1992 to address the development of critical materials needed to meet the requirements of the low-emission, low-noise engines for future high speed civil transport aircraft. These materials included both ceramic matrix composites able to operate continuously at up to 3,000 degrees Fahrenheit in the corrosive and oxidizing environments of low-emission, high-temperature combustors, and metallic and intermetallic matrix composites that retain their properties at up to 2,400 degrees to achieve lightweight exhaust-nozzle components. The focus for the first year of the program was selection of initial material systems and critical test regions for engine components, preliminary screening of candidate fibers and fiber coatings, and evaluation of composite fabrication processes.

NASA's High-Performance Aircraft Research during FY 1992 focused on providing technological options for revolutionary new capabilities in future high-performance fixed and rotary-wing aircraft. NASA's principal concerns here were challenges, such as controlled flight at high angles of attack, that will ensure U.S. pilots continue to fly the best planes in the world. The agency also developed technology to help improve the performance of the current generation of military aircraft.

For example, at NASA's Dryden Flight Research Facility an F-18 **High Alpha Research Vehicle** (HARV) included a multi-axis thrust vectoring system (external inconel steel paddles) for each of its two engines to obtain research results. Test pilots first flew with this configuration in July 1991, the first known flight of a closed-loop multi-axis thrust vectoring system. They completed envelope expansion in February 1992. The system has demonstrated good maneuvering including full rudder pedal sideslips to 65 degrees angle of attack without engine compressor stall and has been effective in increasing the roll rate of the aircraft significantly under certain flight conditions. The F-18 HARV has provided on- and off-surface aerodynamics measurements to correlate against wind tunnel tests and first-ever full aircraft, high angle of attack Navier-Stokes computed flow data. The flight research has provided a wealth of fundamental aerodynamics understanding as well as predictive and design capability applicable to future military and civil aircraft designs.

NASA's **Hypersonic Research** program supported fundamental research into the physical processes of flight at hypersonic speeds; it is also developing new, innovative technologies that will allow future air-breathing, hypersonic vehicles to operate safely in the hypersonic environment. The basic research in six aerospace disciplines concentrated on technical advancement for the next generation of aerospace vehicles rather than a commitment to develop specific technologies for particular missions. As one example of achievements in FY 1992, a high-energy, long-duration, hydrogen-fueled test facility (developed at Ames Research Center) tested an advanced scramjet combustor rig to provide data on combustor efficiency and fuel injection concepts at flight conditions between Mach 9 and 13.

NASA also completed research in FY 1992 on **F-16XL Supersonic Laminar Flow Control**. It modified its F-16XL aircraft by installing an active suction, porous-skin glove on the left wing. Rockwell International engineers designed the glove's shape and active suction system to provide laminar flow over the surface at supersonic speeds. NASA conducted the flight experiment at its Dryden facility in cooperation with the Langley Research Center. During the test program lasting until September 1992, laminar flow exceeded 25 percent chord at supersonic Mach numbers. The test matrix mapped the effects of Mach number, altitude, angle of attack, and suction. This technology has application to a potential high speed civil transport, reducing its take-off gross weight by 4 percent and reducing fuel consumption.

NASA's Critical Disciplines Research during FY 1992 focused on pioneering the development of innovative concepts and providing physical understanding and theoretical, experimental, and computational tools required for efficient design and operation of advanced aerospace vehicles. For instance, in a cooperative research effort to demonstrate aeroelastic stability through active control of wing flexibility, Rockwell International designed and built an Active Flexible Wing (AFW) model that NASA's Langley Research Center tested in its transonic dynamics tunnel. The AFW concept consists of a wing designed with significantly less than normal stiffness in order to reduce weight. Other features include computer-driven flight control surfaces (active controls). These suppress the instabilities that the less stiff wing would otherwise be subject to and permit tailoring of maneuver schedules to minimize structural loads and enhance aircraft performance. This concept is a useful capability for advanced high performance vehicles. The accomplishments of this program include successful flutter suppression tests of the AFW model and the design, fabrication, coding, and successful operation of the digital controller. The results from this program have indicated that multiple active control surfaces can be used to provide variation in the wing shape for better roll and maneuver load control. Measurements from the tests have been used to validate analytical models of the concept for use in design.

In the area of **Computational Fluid Dynamics** (CFD), NASA has developed advanced computational methods for use in more accurate and efficient prediction of aircraft aerodynamic performance as well as for exploration of phenomena in the field of fluid physics. Computational methods research has also emphasized the development and validation of advanced analytical tools, including improved methods for configuration surface modeling and grid generation.

For example, NASA's Ames Research Center successfully computed the flow field of a full F-18 configuration with an advanced forebody flow control system. Wind tunnel tests have shown that this control method provides substantial lateral-directional control at high angles of attack. Conventional control devices normally are inadequate for control at high angles of attack, causing a dangerous condition for fighter aircraft flown into this condition. Pneumatic flow control blows air out of slots on the forebody to energize the boundary layer and control the strong forebody vortices that form at high angles of attack. The calculations show good correlation to sub- and full-scale wind tunnel tests on similar configurations. Consequently, researchers have used the calculations to refine designs for wind tunnel testing.

During FY 1992, NASA was also developing a capability to analyze complete aircraft engines computationally. The advantages of this strategy included mating components within the simulation before cutting hardware or running engine tests as well as "up front" interaction among engine component design teams. However, the complexity of these engines has required simplifying geometric and physical assumptions to make calculations manageable on today's supercomputers. In FY 1992, researchers at NASA's Lewis Research Center successfully analyzed the interior of the engine with the fan and part of the compressor stage, assuming that the air flow was parallel to surfaces with non-zero velocity (inviscid assumption). The direction for future development was the more accurate but complex viscous analysis (zero velocity at surfaces) for all engine components combined.

In related developments, NASA's **High Performance Computing and Communications** (HPCC) program is part of a new Presidential initiative aimed at producing a 1,000-fold increase in supercomputing speed and a 100-fold improvement in available communications capability by 1996. NASA will subsequently use these unprecedented capabilities to help maintain U.S. leadership in aeronautics as well as applications to Earth and space science. As background to the initiative, the limited powers of today's supercomputers are forcing researchers to use simple, single-discipline models to simulate the many aspects of advanced aerospace vehicles as well as phenomena on Earth and in space. This is more costly and time-consuming than simulating entire systems at once, but it has become standard practice due to the complexity of more complete simulations and the limited computing power available to perform them. NASA has focused its efforts under the HPCC program on a variety of technologies that will improve the design and simulation of advanced aerospace vehicles, allow people at remote locations to communicate more effectively, and increase scientists' abilities to model the Earth's climate and forecast global environmental trends. Recent accomplishments include work in computational fluid dynamics, structures simulation, multidisciplinary computation, software exchange, networking technology and systems software, as well as participation in the Concurrent Supercomputing Consortium (CSCC).

NASA has played an active role in the CSCC during its first year of operation. Use of the consortium's **Intel Touchstone Delta** supercomputer has enabled major advances in several scientific and engineering applications including the processing of 3-dimensional images of Venus taken by the Magellan satellite at the rate of four frames per second, bringing real-time image processing within reach. Other accomplishments on the Delta include the largest direct numerical simulation of the time-dependent compressible Navier-Stokes equations and the largest 3-dimensional compressible turbulence simulations for high Reynolds numbers. Additionally, the consortium has provided fundamental insights into computer science issues that are being used to accelerate the development of the next generation of supercomputers.

NASA's Ames Research Center has ported single discipline CFD codes to a number of massively **Parallel Computers** including the Thinking Machines CM2 and Intel iPSC/860. It has obtained the best performance to date on the iPSC/860–performance approximately equal to twice the speed of a single processor on a Cray YMP supercomputer. Ames engineers have simulated two applications involving moderately complex geometrics in the parallel computer environment. These include a High Speed Civil Transport (HSCT) vehicle complete with wing, fuselage, and four engine nacelles and a simple powered lift vehicle, which includes a wing and two lifting jets that are operating in a ground-effect environment. The success of these preliminary simulations will lead to significant enhancements in computer simulation of aerodynamic performance and therefore to more efficient and cost-effective aircraft and spacecraft design.

NASA's Langley Research Center is working to improve the processes for designing advanced aircraft and spacecraft through the use of advanced computational fluid dynamics and structural analyses. Langley's efforts are focusing on the design and analysis of a **High Speed Civil Transport**. One of the greatest challenges in modeling the fluid dynamics of these vehicles is developing mathematical equations that accurately simulate turbulent airflow, because at high speeds, turbulent flow simulations become less reliable. Langley researchers decided the best results could be obtained by performing the simulations on the most powerful supercomputer available. They rewrote computer code designed to simulate turbulence on a Cray YMP so it would run on the more powerful Intel Touchstone Delta supercomputer, using half of its 512 processors. As a result, the simulation occurred approximately 12 times faster than using the Cray YMP's single processor, enabling researchers to simulate high-speed turbulent airflow more accurately.

The development of an optimal airframe design for a high-speed aircraft involves thousands of design iterations, each requiring a large amount of computing time to recalculate how changes in one part of the design ripple through the rest of the structure. Langley Research Center scientists have developed a way to streamline the process and reduce the amount of computing time needed for each iteration. Using equations to determine the inter-relationships of elements in the simulated structure, researchers solve them to determine the vehicle's structure. They have discovered that parallel processing is ideal for generating the elements but inefficient at assembling the structural equations. The researchers overcame this problem and speeded up the process by developing a parallel node-by-node assembly algorithm and running it on the 512-processor Intel Delta. With this and a ring communication technique, they increased processing speed by a factor of 22 over the Cray YMP. Researchers will now use these results as part of an interdisciplinary aerodynamics/structural dynamics design system.

Under the heading of **Benchmarking Multidisciplinary Codes on Parallel Supercomputers**, NASA is also developing the ability to simulate two or more disciplines in a single computer simulation (e.g., the deflections associated with an aircraft's structure and the loads associated with its aerodynamics). Ames Research Center has developed and demonstrated the ENSAERO computer code, which couples aerodynamics and structures analysis modules on the Intel iPSC/860 massively parallel computer. Results involve the coupling of a low-fidelity structures code to a high-fidelity aerodynamics analysis routine. Specific simulations obtained on parallel as well as conventional supercomputers include the analysis of aeroelastic performance about flexible wing and wing/fuselage geometrics for a variety of unsteady maneuver conditions. This multidisciplinary research, coupled with the improved performance offered by massively parallel computers will greatly enhance the ability of aircraft manufacturers to analyze different design options rapidly and then produce vehicles efficiently with optimal performance and reduced design cycle costs.

The inherent size and complexity of HPCC problems will make it more expensive to develop and maintain applications software and more difficult to make it robust. Software reuse can mitigate these effects. The **High Performance Computing Software Exchange** aims at providing an infrastructure that encourages software reuse and the sharing of software modules through an interconnected set of software repositories. Researchers have set up an experimental system that connects software repositories over a number of Federal agencies. They have also developed a series of metrics to compare a variety of alternate computer architectures. Among other benefits, this system will unify existing databases and bibliographic archives as well as reduce costs.

As the year ended, NASA was continuing its pursuit of developing advanced networking technologies to allow researchers and educators to carry out collaborative research and educational activities, regardless of their location or computational resources. Existing networks typically exchanged information at the rate of 1.5 megabits per second (mbps), but this is too slow for projected needs, which entail instantaneous exchange of data. NASA entered into a cooperative effort with DoE to procure network services that operated at 45 mbps using synchronous optical fiber network standards. Under the interim **National Research and Education Network**, the two agencies selected Sprint to provide access to a nationwide fiber optic network that will help meet communications needs and serve as the foundation for even faster networks ranging from 155 mbps to eventual gigabit speeds.

Since the HPCC program is multi-agency and interdisciplinary, it is important to have a coordinated plan for developing **Systems Software and Tools**. As the lead agency for coordinating this effort, NASA organized and directed a workshop of experts from industry, academia, and Government to review existing software and tools for high performance computing environments and identify needed developments. A technical report summarized their findings, which will help formulate a national perspective on requirements in systems software.

Air Traffic Control and Navigation

Among the many programs of the Federal Aviation Administration (FAA), its **Terminal Air Traffic Control Automation** effort sought to provide optimized terminal traffic flow for the air traffic system by expeditiously incorporating proven automation technology. The agency had completed development of a Converging Runway Display Aid (CRDA) to allow continued use of a pair of converging runways during instrument meteorological conditions. A follow-on effort, the Controller Automation Spacing Aid, aimed to extend CRDA technology to other applications to improve throughput of aircraft to the runway. On another project, the Center-TRACON (Terminal Radar Approach Control) Automation System (CTAS), NASA and the FAA were jointly evaluating new technology so as to reduce delays, improve airport flow rates, and permit more fuel-efficient aircraft descents. Following installation at Stapleton International Airport near Denver in March 1992, the CTAS elements began test operations. The principal element of the three-part system was the traffic management advisor. It looked at aircraft from all directions and developed a plan to handle traffic effectively. The descent advisor then generated graphic representations of spatial and time relationships among aircraft converging on the aerial "gate." The final approach spacing tool let controllers make precise corrections to aircraft positions after the planes had flown through the gate. Controllers could use CTAS to determine the best flight routes, including descents, for all types of aircraft. The system constantly updates its advisories based on radar and weather information, knowledge of each aircraft's performance characteristics, and results of commands given by controllers to the aircraft. A second prototype of the equipment was scheduled for test at the Dallas-Fort Worth Airport. In such operational environments, prototypes could be refined in a monitor control mode without disrupting the air traffic control process. The system had the potential to reduce controller workload, improve traffic efficiency, and enhance safety in the terminal air traffic system.

Another FAA program was the **Traffic Alert and Collision Avoidance System** (TCAS). It used air-to-air interrogations of transponder-equipped aircraft to provide pilots with traffic advisories indicating the range, bearing, and altitude of aircraft posing a potential threat. TCAS I, a low-power system that will provide alerting without recommended escape maneuvers, will be required in turbine-powered airplanes with 10 to 30 passenger seats in the mid-1990s. The TCAS II version, which not only alerts the pilot to traffic but also advises whether to climb or descend when a potential threat of collision occurs, involves aircraft equipped with altitude-reporting transponders. TCAS II will be mandatory in all aircraft of more than 30 seats by December 31, 1993. The FAA implemented a transitional program to monitor the performance of TCAS II systems, approximately 4,000 of which were in operation by the end of FY 1992. The agency continued to develop minimum operating standards for TCAS III, which will provide traffic alerts and resolution advisories that include right or left turns as well as altitude changes.

In another area, **Aircraft Digital Systems**, the FAA in cooperation with NASA continued to perform flight safety research relative to validation of software-based digital flight control and avionics systems. The research was in support of FAA specialists in certification and national resources. The FAA published new handbook materials on pilot-vehicle interface issues, and at the end of the year, it was researching requirements and technology in the areas of artificial intelligence, expert systems, neural networks, software development, formal methods, flight-by-light, and power-by-wire.

In a separate FAA and Coast Guard project, all **Loran-C Transmitters** that served the National Airspace System (NAS) were scheduled to be modified to include a new, automatic signal BLINK feature. Signal BLINK is a change in the transmitted Loran-C signal employed when the signal should not be used for navigation. The automatic feature would act as a back-up to the conventional, manually initiated signal BLINK previously used by transmitter station operators. Installation was scheduled to begin late in 1992 and be completed in 1993. With the automatic BLINK in operation, nonprecision approach procedures will be possible at most airports in the NAS.

The FAA was also evaluating initial algorithms for automated generation of alternative flow management strategies on a testbed system of the **Advanced Traffic Management System**. The purpose of this system was to develop enhanced automated capabilities for air traffic flow management.

The agency was involved with the **Voice Switching and Control System**, which will provide air traffic control centers with efficient and economical computer-controlled voice switching for intercom, interphone, and air-ground communications. As FY 1992 ended, the FAA had started factory acceptance testing in anticipation of delivery to the FAA Technical Center in January 1993.

A further concern of the agency was **Airport Visual Guidance**. An essential part of aircraft movement on airport surfaces is proper guidance during taxiing. A necessary requirement of safe and efficient operations is that the visual guidance systems (lighting, markings, and signs) be designed and maintained so as to avoid any ambiguity in their intended operational use. Runaway incursions involving two or more aircraft or an aircraft and a vehicle were still major threats in 1992. Consequently, the FAA completed an in-service evaluation of a stop bar lighting system at New York's John F. Kennedy International Airport during the year. Results showed that stop bars were useful in preventing runway incursions, and the agency has developed a draft specification of a standard stop bar lighting system that was undergoing in-service evaluation at Seattle-Tacoma International Airport as the year ended. Lighting configuration and controls as well as controller workload issues remained to be resolved, however.

The FAA expanded the pre-departure clearance **Data Link Service** during FY 1992 to include 30 airports, with participation growing to include seven major air carriers and a large number of general aviation aircraft. This data link application has greatly benefitted both pilots and controllers during the first year of operation by reducing workload, frequency congestion, and communication error in clearance delivery. During FY 1992, the FAA also began the development and operational evaluation of the next Tower Data Link Service, the Automatic Terminal Information Service, scheduled for national implementation in FY 1993. The agency installed six data link processors at en route control centers and planned to install the remaining systems next year. These systems provide weather information to pilots on a request/reply basis. The FAA also completed the technical definitions of international requirements for air/ground and ground/ground digital communications. These requirements defined the protocols for exchanging information among air traffic controllers, pilots, and other air traffic control systems. In addition, the agency successfully completed the initial step in validating these requirements and expected to complete a working research and developmental system in 1994.

The agency continued to work on various facets of **Interfacility Communications**. These included the Data Multiplexing Network, which compresses information and allowed for a connection between FAA and military facilities over existing telecommunications links; the National Airspace Data Interchange Network II, a packet switched network to provide switching support for the interfacility exchange of weather and air movement data; and the Radio Communications Link, the backbone of high-capacity microwave communication links providing independent voice and data communication among air route traffic control centers. These communications networks and links were in various stages of development as FY 1992 ended.

In another area of its activities, the FAA used the **Airport and Airspace Simulation Model** (SIMMOD) to analyze alternatives for improving system capacity. The agency linked SIMMOD with the Integrated Noise Model for combined traffic flow and noise analysis. Three-dimensional graphics increased the realism of the model, which more than 200 airlines, airports, private firms, and foreign Governments used. The FAA also upgraded the National Airspace System Performance Capability to generate realistic future schedules and to calculate airport capacities. The agency made the Sector Design Analysis Tool interactive, allowing users to change airspace designs and traffic loading and to test these changes more rapidly. During the year, the FAA Integration and Interaction Laboratory (I-Lab) became fully operational, providing new capabilities for evaluating air traffic control communications, human factors, and the impacts of introducing new control technology. The agency incorporated experience from I-Lab research into planning for the future National Simulation Capability.

The FAA was also involved with development of a **Precision Runway Monitor** to increase airport capacity through safe reduction of constraints on the use of parallel or converging runways during instrument meteorological conditions. The agency sponsored prototype development and testing of an electronically scanned (E-scan) secondary radar with improved display, automated predictor, and visual/aural alerting at Raleigh-Durham airport. The FAA has decided to upgrade the prototype system and commission it for use in 1993. In March it awarded a contract to the Bendix Communications Division for a limited production of five additional E-scan radar systems, one of which will replace the Raleigh-Durham installation. The agency continued to study communications issues and was performing additional simulations using different runway spacings and different numbers of runways (triplets and quads).

In another program, **Airport Surface Traffic Automation**, the FAA sought to develop techniques to prevent runway incursions and more fully automate ground movement, thereby speeding traffic flow and increasing all-weather airport surface capacity. The program will fully automate the tracking and identification of aircraft and ground vehicles, provide a situational display, support interfaces for control of airfield lighting to guide aircraft in low visibility, and support air traffic controllers by providing an automated conflict alert system. This conflict alert system builds on experience gained in developing the Airport Movement Area Safety System (AMASS), a basic set of safety logic to accompany the airport surface surveillance radar, ASDE-3. The FAA will field AMASS in FY 1994 as an interim system if it is successful during engineering trials in FY 1993. Airport Surface Traffic Automation is scheduled as a competitive development program for design in FY 1993, prototyping in FYs 1995-96, and full-scale development beginning in FY 1997.

The FAA also pursued an initiative called the **Terminal Area Surveillance System** to provide safety and efficient air traffic control within the terminal area early in the 21st century. The program will research the capabilities of new sensor technologies to detect and track aircraft, from en route handoff to the airport gate, as well as aviation weather hazards (windshear, wake vortex, hail, etc.). It will also investigate data integration and processing functions necessary to provide weather and surveillance products that support safe and efficient air traffic management operations in the terminal area of the future. During the last year the program office has, among other things, awarded seven contracts through a broad agency announcement and signed a cooperative research and development agreement with one company.

The FAA continued development of the **Microwave Landing System** (MLS). The agency awarded two contracts for the design and development of Category II and III MLSs during the year. One contract went to Wilcox Corporation and the other to Raytheon. Each vendor will produce 6 to 12 first article test systems.

The FAA's **Advanced Automation System** (AAS) will wholly replace the automated equipment previously used in controlling en route and terminal air traffic. AAS will include new computer software, processors, tower position consoles, and controller workstations. The system will increase controller productivity, upgrade the capacity and reliability of the airspace system, and provide the flexibility needed for future enhancements. The system's first element was installed at 16 sites and commissioned at 12 sites during FY 1992. Development of computer codes and software was underway at the end of the year.

The FAA was working with several satellite applications for civil aviation. As the U.S. Navstar **Global Positioning System** (GPS) neared full operational status, civil aviation users were expected to experience a significant change in the way they navigated through the airways. The transition from a ground-based to a space-based navigation system was a major program underway at the FAA. The agency was also cooperating with the International Civil Aviation Organization to exploit rapidly the benefits of a Global Navigation Satellite System (GLONASS). The FAA has reached numerous agreements with foreign countries, such as with the former Soviet Union to examine the use of the Soviet GLONASS, and with Fiji to establish a prototype airspace system using satellite technology for navigation and air traffic control. The FAA and NASA have begun work on establishing the feasibility of using the GPS to satisfy Category II and III precision approach requirements.

In the area of **Vertical Flight Planning**, the FAA continued research and development into issues of rotorcraft infrastructure to improve flight operations in the National Airspace System. Development of a Vertical Flight Program Plan continued in an effort to coordinate project planning data with the goals of the Rotorcraft Master Plan. The agency also drafted plans outlining projects addressing terminal area procedures and noise.

With respect to **Heliports and Vertiports**, the FAA developed several publications on topics such as helicopter accident and risk assessment near heliports, airports, and unimproved sites and on helicopter operations in the Northeast. These reports addressed route standards and air traffic management recommendations to further enhance the utility of helicopter operations between Boston and Washington. The agency also completed an operations analysis of the New York Downtown Manhattan Heliport. Research conducted by the FAA Technical Center resulted in a published report on avoiding potential hazards from magnetic resonance imagery equipment.

Under the FAA's Airport Improvement Program grants, several state and local governments completed **Civil Tiltrotor** (CTR) feasibility studies. A delay reduction study continued to quantify potential benefits of using passenger-carrying tiltrotors for certain short-haul operations from major airports. The agency completed a draft civil tiltrotor research plan addressing CTR steep angle approaches and procedures.

Weather-Related Aeronautical Activities

During FY 1992, progress continued on three efforts the FAA began in FY 1991 to improve **Aviation Weather Services**. Under FAA sponsorship, the National Oceanic and Atmospheric Administration (NOAA) continued development of the Aviation Gridded Forecast System (AGFS). This will provide a higher resolution picture of current and predicted states of the atmosphere over the continental United States. The National Science Foundation continued assisting the FAA in the development of the Aviation Weather Product Generator. This system will create products for the AGFS grid tailored for an en route application, aiding in strategic and tactical decision-making with respect to avoiding weather hazards. The Air Force continued working with the FAA in the development of the Integrated Terminal Weather System (ITWS), which will provide very short-range forecasts and warning notices for pilots and air traffic controllers. ITWS will use AGFS grids and inputs from other available airport terminal sensor systems.

Another FAA system, the **Terminal Doppler Weather Radar** (TDWR), provides timely detection of hazardous wind shear in and near airport terminal approach and departure corridors and reports that information to pilots and controllers. During FY 1992, the agency installed the first two production TDWRs at the FAA Academy in Oklahoma City and at Memphis airport. The third production system was delivered to Houston in September 1992. Also during FY 1992, the FAA started operational testing of the production TDWRs and completed initial TDWR training for air traffic controllers and maintenance technicians.

The FAA and the National Center for Atmospheric Research continued their 6-year program, begun in 1989, to address basic research relating to the **Icing** hazard and to improve forecasting. Included was a demonstration at Denver's Stapleton Airport of non-automatic techniques for improved snowfall prediction to use in conjunction with planned deicing of aircraft on the ground. The National Weather Advisory Unit in Kansas City included in its operations techniques for improving the forecasting of icing aloft. Additionally, the FAA undertook efforts to enhance aircraft ground deicing safety, including investigations of deicing fluids, aircraft surface ice detection technologies, and investigation of the effects of ice roughness on airplane aerodynamic performance.

The FAA was also actively involved in acquiring **Weather Observing Systems**. In cooperation with the National Weather Service, the agency continued a program to acquire Automated Surface Observing Systems by ordering 107 additional systems during FY 1992. Sixty systems were installed by the end of the fiscal year. Twenty-five Automated Weather Observing System (AWOS) Data Acquisition Systems (ADASs) were under contract in FY 1992 as well, with delivery scheduled to FAA air route traffic control centers between 1993 and 1995. The purpose of ADAS was to receive AWOS weather data and to process and distribute it to the National Airspace System. The agency also commissioned 160 AWOS III units.

In its **Electromagnetic Environment Program**, the FAA began collecting the information needed to issue guidelines for fuel tank lightning standards during certification. It continued conversion of the F-106 lightning data to the FAA Research Electromagnetic Database, and it provided draft users' manuals for on-line subscribers. Using its Technical Center's S-76 research helicopter, the agency performed additional tests at Air Force radar sites to determine attenuation factors for High Intensity Radiated Fields (HIRF–emissions that could interfere with electronic systems). It began organizing the 3rd International Conference on HIRF and initiated efforts with NIST to determine the length of time HIRF shielding for airframes on aircraft remained effective. The FAA also published revised and draft documents in support of advisory circulars, as well as user manuals dealing with threats from lightning and HIRF.

Flight Safety and Security

Among many projects to improve flight safety, NASA together with the FAA and industry embarked on a three-phased program to understand, detect, and avoid or recover from **Hazardous Windshear**. Among other things, the project involved testing and development of microwave radar, lidar (laser radar), and infrared sensing technologies for use in detecting hazardous windshear. The FAA has directed that all commercial aircraft must have onboard windshear detection systems by the end of 1993. During the summers of 1991 and 1992 there were flight tests of experimental versions of lidar, radar, and infrared sensors at Denver and Orlando. With prototype windshear sensors installed, the Langley Research Center's Boeing 737 transport systems research vehicle conducted a series of flight tests highlighted by numerous low altitude penetrations of microburst windshear conditions. It safely recorded more than 50 low altitude approaches and penetrations of microburst windshears and strong gust fronts. These flight tests ascertained the windshear measurement potential of the installed sensor systems in the full range of weather conditions. Data of excellent quality from the tests indicated strong potential for airborne sensors to provide accurate predictions of hazardous windshear conditions with ample time for precautionary crew actions.

The FAA's **Low Level Wind Shear Alert System** (LLWAS) measures wind speed and direction from sensors located around the periphery of airports and analyzes these measurements to detect the presence of hazardous windshear. Phase-2 systems upgrade the basic LLWAS with a microburst-detection algorithm developed by the National Center for Atmospheric Research. Two prototype phase-3 systems, in operation since 1988, have a record of effectiveness that includes a documented save. During FY 1992, the FAA continued expansion of LLWAS to a phase-3 configuration.

The FAA also completed an analysis to determine which of several candidate **Ground-Based Windshear Systems** would be the most cost effective for detecting the windshear hazards at major U.S. airports. The study concluded that 83 LLWASs should be upgraded to be equivalent to the operational prototype design at Stapleton Airport. The study also recommended that all 45 TDWR systems should be integrated with LLWAS. Field tests showed that when integrated, the two systems were complementary and provided a very high performance windshear detection capability. The study indicated that at airports without a planned TDWR it would be cost effective to add a windshear processor to 58 recent generation Airport Surveillance Radars (ASRs) rather than to procure more TDWRs. The FAA therefore created a new project, the ASR Windshear Processor (WSP), to develop the enhancement. Some ASR WSPs will be integrated with LLWAS and others will stand alone depending on performance requirements at a given airport.

In the area of **Structural Airworthiness**, the FAA conducted an investigation of the effects of plastic media blasting on the crack propagation rates in aluminum panels on aircraft so as to determine safe operating procedures for this type of fuselage paint removal. The tests generated data on the performance of equipment as well as on the metal's ability to absorb impact pressure. In conjunction with the Air Force, the FAA developed a composite failure analysis handbook to assist accident investigators in conducting analyses on failed composite aircraft structures. Also, a joint FAA-Navy endeavor resulted in the identification of all existing data on delamination and analytical analysis relating to composite aircraft structures, delamination being the most common type of defect found in such structures. In addition, the FAA generated and distributed a video on the certification of aircraft tires, identifying all certification requirements and standards including inspection, repair, and tread specification for bias ply and radial ply aircraft tires.

With respect to **Aircraft Crashworthiness**, the FAA conducted a full-scale, vertical impact test of a Fairchild Metro III airframe. This test provided data on a variety of standard and energy absorbing seating systems within a metal commuter airplane fuselage. In addition, the FAA conducted an analysis of rotorcraft ditchings and water-related impacts on accidents that occurred from 1982 to 1989, placing special emphasis on the performance of flotation devices and post-impact occupant survivability. The agency also completed a research program that examined crash resistance technology for civil rotorcraft. The effort identified impact design and test criteria for civil rotorcraft, as well as an assessment of the weight penalties incurred and the technical difficulties in meeting those criteria. The FAA was negotiating agreements with NASA, elements of the DoD, and the United Kingdom's Civil Aviation Administration relating to joint research on the crashworthiness of fixed and rotary wing aircraft.

In related efforts, the FAA prepared and made public a program plan for **Aging Aircraft Research** to be conducted over the next five years. In efforts to make the FAA's and NASA's research on aging aircraft complementary, the two agencies organized eight working group meetings involving their personnel and contractors to discuss ongoing studies on select issues. The FAA concluded international cooperative agreements covering aging aircraft research with its counterparts in the United Kingdom, the Netherlands, Japan, and Australia. At the end of the year, several projects covered by these agreements were underway. The FAA also sponsored two international workshops on structural integrity of aging airplanes and on nondestructive inspection and robotics.

The FAA's **Jet Engine Bird Hazard Program** featured a continued analysis of worldwide data on bird ingestion, providing threat definition and damage characterizations for use in updating engine certification standards and airport bird hazard studies. The agency published an interim report on the initial data from a 2-year study of 7 large, modern, turbofan engine models installed on 8 types of contemporary transports.

FAA research efforts to improve **Airport Runways** included preparing a preliminary design for a national airport pavement dynamic test facility. To improve runway surface technology, the agency continued its runway friction testing, as well as its soft-ground arresting tests.

With respect to **Fire Safety**, the FAA conducted tests to optimize an onboard cabin water spray system that had previously proved to be effective against postcrash fires. Preliminary results indicated that the system's weight could be reduced by two-thirds if the system were zoned, with each zone activated by thermal detectors. Boeing completed an FAA-sponsored study examining the effects of an accidental discharge. The FAA also completed full-scale tests to define design modifications and firefighting procedures to safeguard against cargo fires in combined passenger/cargo aircraft. The results demonstrated the problems associated with fighting the fire by hand and the relative effectiveness of improved design features. The agency also initiated tests in a turbine engine to screen new extinguishing agents being proposed to replace Halon 1301, which will soon be banned from production because of its role in depleting the ozone layer.

In the area of **Aircraft Rescue and Firefighting** (ARFF), the FAA completed a research effort to evaluate and determine the scale of fire protection and equipment requirements for general aviation and heliport operations. The agency initiated efforts to improve ARFF response capability under conditions of poor or limited visibility. This effort will include use of such technologies as satellite mapping and devices for enhancing infrared vision. The FAA started a research effort to evaluate possible replacement agents for Halon 1211, which helped deplete the ozone layer.

With regard to **Aviation Fuels**, the FAA began testing to develop an unleaded aviation gasoline. The agency provided data it generated on material compatibility to industry, tested experimental fuels developed by others, and worked with the American Society for Testing and Materials in developing a specification for both a high octane and low octane unleaded aviation gasoline.

In the area of **Civil Aviation Security**, the FAA was engaged in a number of efforts to comply with the Aviation Security Improvement Act passed by Congress in November 1990. For instance, the agency has embarked on an extensive research and development effort to enhance aviation security through the use of explosives detectors, x-ray technologies, and vapor/particle detection devices. In November 1991, the FAA conducted the First International Symposium on explosive detection techniques, at which representatives of Government, academia, and private industry exchanged relevant information on technological advances. In August 1992, the agency sponsored a symposium on aircraft hardening and survivability to disseminate information on technologies to reduce the vulnerability of commercial aircraft to explosive threats. An FAA explosives detection research laboratory at the agency's Technical Center was nearing occupancy and will permit research, testing, and evaluation of a full range of detection technologies applicable to security. The agency also continued defining requirements for an explosives detection system. This may employ any of several different explosives detectors as part of an automated system to screen carry-on and checked baggage, mail, and cargo.

The FAA continued its program in **Turbine Engine Rotor Failure Safety** to identify technology that will provide a means of protecting aircraft against the hazards of turbine rotor failures. It continued research and development of a variety of advanced, lightweight materials designed as barriers to absorb the high-energy fragments liberated by small turbine engine failures. Testing in a rotor-spin facility established the geometrics of penetration threshold thickness. The agency initiated programs that will provide prototype demonstrations of a unique x-ray system to detect cracks in an operating engine, plus a computer-based methodology for an integrated system to predict failure of rotating parts in turbine engines.

In another project concerned with improving flight safety, NASA was developing **Thermographic, Nondestructive Evaluation Techniques** to detect disbonds in lap joints on aircraft fuselages. The process involved increasing the temperature of the outer surface of the lap joint by application of heat from quartz lamp heaters. Then an infrared imager sensed the surface's thermal response. The system was noncontacting, could inspect one square meter in less than two minutes, and had no difficulty inspecting curved surfaces. Results of measurements on samples with artificially fabricated disbonds showed the technique was able to indicate them clearly. United and Northwest Airlines' rework facilities successfully demonstrated the technique on their Boeing 747 aircraft.

In still another development having to do with flight safety, in August 1992 the FCC amended Part 87 of its rules to establish technical standards and licensing procedures for **Aircraft Earth Stations**. These were mobile stations in the Aeronautical Mobile-Satellite Service or Aeronautical Mobile-Satellite (Route) Service that were located aboard aircraft. The stations provided communications in support of domestic and international air traffic, including air traffic control and safety-related communications. The adoption of appropriate technical standards will foster the rapid introduction of new aircraft radio communications equipment, permitting aircraft to participate extensively in the benefits of satellite communications and helping U.S. industry to remain internationally competitive. Since satellite communications were much more reliable than high frequency communications, the new stations will improve safety communications and should relieve some of the congestion in high frequency and very high frequency communications bands.

Aviation Medicine and Human Factors

In the **Human Factors** area, NASA and the FAA continued the fatigue countermeasures program to provide both understanding of the phenomena of flight crew fatigue, inattention, and jet lag and a program of countermeasures to aid in reducing human error and improving performance. On trans-Pacific commercial flights, crews performed flight tests of new countermeasures to fatigue. Extensive comparisons of data on crews with no rest and pre-planned cockpit rest showed superior sustained performance and reduction in errors among the latter. As a result, the FAA has prepared a draft advisory circular entitled "Controlled Rest on the Flight Deck Program," which will allow pre-planned cockpit rest. At the end of the fiscal year, the draft was being reviewed by an Air Carriers Operations subcommittee as part of the year-long public comment period required for changes in Federal Air Regulations.

The FAA conducted many other projects in the human factors area as well. For instance, it completed a cooperative pilot/controller study of altitude deviation incidents with the participation of an airline, the Airline Pilots' Association, and the National Air Traffic Controllers Association. Working with a major airline, the agency also developed a tool for the combined evaluation of flight technical skills and crew resource management proficiency. It also signed an interagency agreement with NASA for the joint acquisition of a B-747-400 flight simulator to be used for human factors research.

In the field of **Aviation Medicine**, the FAA worked on such projects as determining incapacitation levels for carbon monoxide and hydrogen cyanide that may transit breathing gear. It conducted proof-of-concept studies of various means of attenuating head injury in aircraft crashes. To give but one other example, the agency completed an analysis of information on age and experience with respect to aircraft accidents so as to evaluate the relationship between the two variables.

Studies of the Planet Earth

Uses of Remote Sensing

During FY 1992 a variety of Governmental departments and agencies employed remote sensing from either satellites or aircraft for a great diversity of land-based purposes. Among these departments and agencies, the **U.S. Department of Agriculture** (USDA) itself had a plethora of such uses for remote sensing, especially of Landsat data, of which the Department was the largest user outside the DoD. For example, the Forest Service acquired high altitude, color, infrared aerial photographs of the Pacific Northwest from NASA to assess forest decline resulting from severe insect outbreaks, five consecutive years of drought, and catastrophic fires. It will incorporate the resulting information into a geographic information system that will assist the agency to address the problem.

The **Forest Service** has also used satellite remote sensing since the launch of the first Landsat satellite in 1972. In 1992 it was engaged, among other projects, in processing satellite images of the Flathead National Forest in Montana to update and monitor vegetation changes, grizzly bear habitat, old growth, and numerous wildlife applications throughout the 2.5 million acre area.

The **Agricultural Research Service** of USDA also had many uses for remote sensing. For instance, beginning at the end of FY 1991 it began working with the Space Remote Sensing Center of NASA's Stennis Space Center to investigate the potential for employing a multispectral video imaging system in agricultural management. The Service assembled a high resolution video system and used it to assess a variety of crops in Wisconsin. In addition, NASA tentatively agreed to include this video system on a space shuttle mission in 1994.

The USDA's **Foreign Agricultural Service** used remotely sensed data to assess foreign market supply, among other purposes. One such project involved assessment of the low grain production in the middle Volga Valley in Russia as a result of a prolonged dry period and high temperatures in June 1992. The Service used satellite imagery, remotely sensed weather data, and a barley yield model together with geographic information system analysis to assess the loss in yield and thereby help in the larger process of determining the foreign markets for U.S. farm commodities.

Use of digital satellite imagery was widespread within the **Soil Conservation Service** (SCS) during FY 1992. Several SCS offices used data from the Landsat thematic mapper as well as from the Landsat multispectral scanner and French SPOT (satellite for the observation of the Earth) multispectral images to extract Earth cover information from areas as small as a single watershed to those as large as a river basin. SCS used digital satellite image data to determine Earth cover changes in six states. Remote sensing data collected by state departments of natural resources were routinely converted to a common format and distributed to state and field office locations, as well.

One final example of the USDA's many applications of remote sensing was its employment of the Computer Aided Stratification and Sampling (CASS) system, which used digital satellite imagery together with mapping data to stratify areas of land based on the percent cultivated and/or the land use. The **National Agricultural Statistics Service** (NASS) and NASA's Ames Research Center had jointly installed CASS in 1991. In FY 1992 NASS used the system and Landsat digital imagery to stratify Oklahoma completely and begin the stratification of California for the June 1993 Agricultural Survey.

The Department of the Interior likewise had multiple applications of remote sensing. For example, in 1992 the **U.S. Geological Survey** acquired over 237,000 square kilometers of additional Side-Looking Airborne Radar (SLAR) coverage for geologic, hydrologic, cartographic, and engineering applications in AL, MS, GA, FL, KS, CO, and UT. The Survey also provided emergency response information from its Earth Resources Observation System (EROS) Data Center in the form of aerial and satellite images in support of relief efforts following Hurricane Andrew and forest fires in the Western United States, among other emergencies. And it used digital Landsat data from two periods during the growing season to identify the areas of agricultural crops irrigated with water from the Edwards aquifer in south-central TX. The results of the last effort were found to be quite accurate when compared with independent estimates of irrigated crop acreage of the same area.

The U.S. Geological Survey was also supporting the U.S. Agency for International Development's Famine Early Warning System project by providing technical support and satellite derived products to help assess the nature and extent of the drought and famine in Zambia, Zimbabwe, Malawi, and Mozambique. The effort entailed mapping agricultural lands in the region from Landsat data, creating additional digital data layers (administrative units, population data, roads, cities, etc.), and using NOAA AVHRR (see below) data to identify areas and populations that have been most severely impacted by the drought.

In the area of cartography, the Geological Survey continued its development of the digital orthoptoquad, an image product derived from rectified aerial photographs in which displacements due to terrain relief and camera tilt have been removed, as a product of the National Mapping Program. The digital orthoptoquads will serve as the primary source for revision of the Survey's 1:24,000-scale topographic map series, and the

Survey was also cooperating with other Federal agencies to establish orthoptoquad production standards and to provide demonstration products for such applications as land use monitoring, soil surveys, and as a base for geographic information systems.

The **Bureau of Reclamation** continued numerous applications of remote sensing to a variety of resource management objectives. These included mapping irrigated lands in the Upper Colorado River basin from high altitude, color-infrared aerial photographs. Researchers interpreted information about irrigated agricultural fields from the aerial photographs, transferred it onto a planimetrically correct map or orthophoto base, then digitized it into a geographic information system. The latter will be used to model consumptive water use within the entire Upper Colorado basin. The Bureau also used aerial video and aerial photographs for other purposes, such as to map endangered fish habitat along the Pecos, San Juan, Green, and Colorado Rivers.

The **Bureau of Indian Affairs** continued to conduct resource inventory and assessment projects to support its Indian Integrated Resource Information Program. Landsat Thematic Mapper data served, for example, to classify land cover, with emphasis on modeling fire fuels potential on the Jicarilla Indian Reservation, NM, and for woodlands mapping on reservations throughout southern SD.

The **Bureau of Land Management** obtained both satellite data and aerial photographs to aid in public land management. In addition to participating in the multiagency, multi-state National Aerial Photography Program (NAPP), which awarded contracts totaling nearly $3.8 million in FY 1992 for aerial photography, the Bureau acquired aerial photographs for approximately 22,300 square kilometers of portions of AZ, CO, ID, and OR for recreation site development, mineral development operations, wilderness study analysis, and forest and rangeland monitoring, among other applications.

The **National Park Service** continued its extensive work developing vegetation community types from Landsat Thematic Mapper data in the Alaskan national parks. During 1992, it completed mapping at Yukon-Charley National Rivers, among other projects either ongoing or newly started.

The Minerals Management Service was using the **GPS** as a surveying and mapping tool in a pilot project to locate and position low water features accurately in the Gulf of Alaska to support offshore natural resource management activities. The accuracy of the resulting information has significantly reduced litigation between the Federal Government and coastal states. Similarly, the Office of Surface Mining Regulation and Enforcement has used GPS as a mapping and construction design tool, while the U.S. Geological Survey has applied its data to determining point and land-surface elevations and to monitoring land subsidence, among other uses.

The **U.S. Bureau of Mines** has assembled a multidisciplinary team to study the utility of remote sensing for characterizing and inventorying mine waste as part of its Hazardous Waste Program. During 1992 it conducted research to identify the most suitable type(s) of remote sensing (satellite, airborne scanner, or aerial photograph) and the appropriate field verification procedures. It chose mill tailings sites with known production history and background data in Leadville, CO, and Midvale, UT, then collected and evaluated the available satellite images and aerial photography. Preliminary results indicate that near-surface base-metal concentrations can be detected indirectly by short-wave infrared response to minerals formed by oxidation of metal sulfides in the mill wastes. Relatedly, the Office of Surface Mining Regulation and Enforcement and the state regulatory agencies that enforce the Federal Surface Mining and Control and Reclamation Act continued to use aerial photographs to design, monitor, and reclaim surface mines.

Somewhat analogously, the **U.S. Environmental Protection Agency** (EPA)–primarily through its Environmental Monitoring Systems Laboratory in Las Vegas, NV (EMSL-LV), with assistance from its Atmospheric Research and Exposure Assessment Laboratory in Research Triangle Park, NC–routinely conducted research and provided technical support using remote sensing as part of its overall environmental monitoring program. The agency used large-scale aerial photography to develop site characterization data during the remedial investigation and feasibility study conducted as part of remedial actions under the Comprehensive Environmental Response, Compensation, and Liability Act, as well as to support site selection and monitoring at hazardous waste facilities operated under the Resource Conservation and Recovery Act. In this connection, airborne multispectral scanner data and satellite imagery also played a part in helping engineers develop detailed site characterizations. The agency developed and used remote sensing systems to support the provisions of the Clean Air Act. In FY 1992 the EMSL-LV completed more than 300 aerial photographic site characterizations. Aerial photography and satellite data also supported a broad variety of pollution, global change, pollution prevention, compliance, and other ecosystem monitoring studies in FY 1992, such as those of critical-habitat areas for wildlife. In addition, the EPA was using and developing (with NASA support) light detection and ranging systems to monitor urban plumes and emissions sources as well as to measure ozone, sulfur dioxide, and particulates. Finally, it was using a geographic information system for data integration and analysis in support of many of its programs.

Environmental Concerns

Besides the applications of remote sensing to environmental matters, already discussed, there were numerous other aeronautical- and space-related environmental activities in FY 1992. For example, in its continuing effort to enhance technical capabilities to deal with environmental issues, the **FAA** developed a computer tool known as Integrated Noise Model (INM) Version 3.10. This included an expanded aircraft database for better simulation of aircraft performance. The agency also completed an analysis of noise abatement procedures for the departure of large turbojet aircraft. This analysis supported the development of a new advisory circular to be issued on the subject. The FAA implemented a computer bulletin board system to provide analytical and software support to the world-wide group of users of the agency's environmental tools. In a joint effort with the Air Force, the FAA issued an updated version of the Emissions and Dispersion Modeling System (EDMS), an EPA-approved computer model for the assessment of air quality around airports. In addition, the agency created and released the FAA Aircraft Engine Emissions Database (FAEED), which contained emissions factors for various aircraft engines and data correlating engines to specific aircraft. Finally, in the area of vertical flight operations, the FAA continued its research into steep angle approaches to heliports and vertiports as well as noise abatement control procedures. In coordination with NASA and with significant participation by industry and academia, the FAA continued to identify goals and requirements for vertical flight noise certification and noise abatement procedures. (For other environmentally related efforts, see Aeronautical Activities, Technological Developments.)

Another key environmental effort in FY 1992 was **Monitoring Ozone Depletion**. One of the major Earth science highlights of FY 1992 was the discovery that, like the ozone layer over the Antarctic with its well-documented annual depletion, the ozone layer in the Northern Hemisphere is increasingly vulnerable to depletion by synthetic chemicals. Results from the Second Airborne Arctic Stratospheric Expedition (AASE-II), a six-month study of the atmosphere using NASA research aircraft, correlated with observations from the Upper Atmosphere Research Satellite (UARS), launched in September 1991, contributed to increased understanding of the degree and nature of ozone depletion in the Northern and mid-latitudes. AASE II revealed that during the winter of 1991-92, the Northern Hemisphere had a high concentration of ozone-depleting chemicals in the stratosphere, but early warming in late January precluded major ozone depletion. In conjunction with UARS data, information from AASE-II also revealed important evidence that ozone decreases in the mid-latitudes were associated with increased levels of synthetic chlorine and bromine compounds in the stratosphere.

In conjunction with AASE-II, reported results of lower-than-expected ozone losses over the Northern Hemisphere included data provided by an SAO-built far-infrared spectrometer flown aboard a NASA DC-8 in January-March. The experiment also set new upper limits for hydrogen bromide in the atmosphere, a result representing a first step toward understanding the potential impact of ozone-threatening bromine compounds. On subsequent balloon flights, the instruments produced measurements of stratospheric chemical abundances that complemented observations by UARS.

Measurements from NASA's Total Ozone Mapping Spectrometer (TOMS) instrument on the Nimbus 7 spacecraft, in orbit since 1978, revealed that ozone levels over the Antarctic once again reached record lows in October 1991. This data, combined with that from UARS, AASE-II, and other research led the Administration and the Congress to speed up the U.S. phase out of chemicals that deplete the ozone layer.

Atmospheric Sciences and Oceanography

Beyond research on ozone, efforts to understand the atmosphere–and any potential greenhouse effect–took a number of forms in FY 1992. All such Federal efforts were part of the U.S. Global Change Research Program, established by the President to organize all research aimed at studying our changing Earth. As discussed in part above, the **ATLAS-1** Spacelab flew aboard STS-45 in March 1992 on a successful mission to study the atmosphere. This was the first in a series of such spacelabs that will study solar output plus the chemistry and dynamics of the middle atmosphere over a solar cycle of 11 years. These measurements are important because even small changes in the Sun's total irradiance or its spectral distribution can have a significant impact on the Earth's climate. Similarly, changes in the quantity and distribution of trace species in the atmosphere can have both climatic and other effects. In addition to a core set of instruments focusing on these areas, ATLAS-1 also included instruments to study space physics and ultraviolet astronomy. Scientists are also using ATLAS-1's measurements to correlate data from the UARS. The ATLAS series will repeatedly fly a core set of instruments that are recalibrated after each mission. This will enable scientists to differentiate between changes in the way UARS instruments measure over time and actual atmospheric phenomena.

Also in relation to the ozone layer as well as the greenhouse effect, **NIST** had several projects ongoing in FY 1992. One used molecular spectroscopy to provide the data for monitoring molecular species present in trace amounts in the Earth's atmosphere. NIST and NOAA were collaborating on measurements of concentrations of hydroxyl, water, ozone, chlorine, oxygen, and some nitrogen-oxygen compounds. Scientists were compiling data from these and other measurements into database tables that will enable atmospheric modelers to predict equilibrium conditions for the atmosphere and its chlorine pollutants.

In a separate, NASA-sponsored project on isotopic characterization and modeling of trace gases and particles in the atmosphere, NIST scientists were employing the institute's unique capabilities for tracing atmospheric carbon by state-of-the-art isotopic measurements. They sought to identify regional and global sources of important "greenhouse" gases–carbon monoxide, ozone, carbon and sulfur aerosols, and others that affected the quality of the atmosphere and the climate. The project included a world-wide database of isotopes in the atmosphere; it aimed at a comprehensive review article of isotopic data, measurements, and applications.

NIST also completed experimental determinations of rate constants and tropospheric lifetimes for the reactions of the hydroxyl radical with a series of fluorinated ethers under consideration as alternatives to chlorofluorocarbons (CFCs). Results indicated that several of the proposed fluorinated ethers had tropospheric lifetimes permitting them to be viable CFC replacements. NIST researchers completed similar measurements for reactions involving compounds proposed as alternatives to the halon fire suppressants.

Further aiding environmental efforts, NASA and the U.S. Geological Survey cooperated with the United Nations to establish the United Nations Environment Program (UNEP) **Global Resource Information Database** at the U.S. Geological Survey's EROS Data Center. It served to expedite the collection, compilation, and international distribution of global data sets to support global environmental investigations.

Also relevant to environmental as well as atmospheric concerns were the **NOAA-9, NOAA-10, NOAA-11, and NOAA-12** satellites, which continued to provide polar-orbiting services. NOAA-9, launched in December 1984, operated in a standby mode, providing ozone data from its Solar Background Ultra-Violet instrument. Launched in September 1986, NOAA-10 was also operating in a standby mode and providing limited Earth Radiation Budget Experiment data. NOAA-11, launched in September 1988, provided the primary afternoon meteorological satellite coverage, while NOAA-12, launched in May 1991, provided comparable morning coverage. Using observations from these satellites, NOAA scientists assembled a data set of total ozone amounts for the period 1979-92. Infrared sounders on the various satellites operating in this period were the sources of these data. NOAA scientists were in the process of analyzing the data set for the time histories of globally-distributed total ozone amounts and of the annual depletion of ozone over Antarctica. Scientists will eventually combine these data with information derived from the Solar Backscatter Ultraviolet instruments that have been flying on NOAA satellites since 1985. The result will be a consistent and credible ozone time series usable in climate and global change studies.

A major step in understanding the oceans came on August 10, 1992, when the U.S. and France successfully launched the joint Ocean Topography Experiment, **TOPEX/POSEIDON**, aboard an Ariane 42P expendable launch vehicle from the European Space Center in Kourou, French Guiana. This was the third mission to fly as part of NASA's Mission to Planet Earth–UARS and ATLAS-1 being the first two. The most advanced scientific ocean-observation satellite to date, TOPEX/POSEIDON uses radar altimetry to measure sea surface height over 90 percent of the world's ice-free oceans. In combination with very precise determination of the spacecraft's orbit, the altimetry data will yield global maps of the oceans' topography with accuracies to within 3 centimeters (1.2 inches). From this data, scientists will be able to determine the speeds and directions of ocean currents worldwide, thereby gleaning greater understanding of the Earth's climate. The data from this mission, in concert with ship and aircraft research, will produce complex computer models of global climate. TOPEX/POSEIDON's measurements will be supplemented by data from other spacecraft, such as the European Remote Sensing Satellite (launched in 1991), the Japanese Advanced Earth Observing Satellite (to be launched in 1996), and the Earth Observing System (EOS) platforms (to be launched beginning in 1998, constituting the second phase of Mission to Planet Earth).

Efforts to understand the Earth as a system moved forward as NASA restructured the **EOS** program in early FY 1992 to adapt to potential funding constraints and to take advantage of new launch opportunities. EOS spacecraft are designed to provide insight into how the Earth's atmosphere, land, ocean, and life interact by having a variety of different instruments make simultaneous measurements of the planet. As a result of the restructuring, EOS instruments will now fly on a number of small and intermediate spacecraft, rather than on larger platforms. NASA reduced overall EOS development costs through FY 2000 from $17 billion to $11 billion, primarily by focusing the mission on global climate change, altering the development schedule, and dropping a few of the planned instruments. In mid-1992 NASA further rescoped EOS in order to reduce its budget through FY 2000 from $11 to $8 billion. This occurred without significant changes to the scientific complement by moving to a common spacecraft approach, adopting a cost-driven approach to instrument development, reducing the number of data products required before launch, deleting one instrument, and relying more on other agency and international partners to meet some scientific requirements.

Relatedly, development continued on NASA's **EOS Data and Information System** (EOSDIS), a state of the art data and analysis system that will offer unprecedented research access to data from EOS and other NASA Earth science missions and will tie into the larger effort to make all Federal global change data more readily available to scientists and the general public.

In addition to all of the above, NOAA kept not only the NOAA series of weather satellites in constant Sun-synchronous polar orbits but also (normally) two **Geostationary Operational Environmental Satellites** (GOES) in geostationary orbit. However, a launch failure in May 1986 destroyed a GOES spacecraft, preventing replacement of a worn GOES satellite that failed in 1989 after many years of service. From 1989 through 1991, GOES-7 covered both the Atlantic and Pacific Oceans from 108 degrees west longitude in winter and moved in summer and early fall to 98 degrees west longitude to observe the formation of Atlantic hurricanes. Beginning in January 1992, pursuant to a contract signed with ESA and the European Meteorological Satellite Program (EUMESAT), the Meteosat-3 has been positioned at 50 degrees west longitude to assist in providing Atlantic coverage and permit GOES-7 to remain positioned further west at 112 degrees.

NOAA's new series of five satellites, designated GOES-I through -M, was under development through a contract with Space Systems/Loral, which had purchased Ford Aerospace and Communications Corporation, the original contractor. Work on the first two spacecraft of the series included instrument fabrication and testing by the Aerospace/Communications Division of International Telephone and Telegraph. This program has experienced significant technical problems, schedule delays, and cost increases. A concerted effort by Space Systems/Loral, including augmented support by NASA, NOAA, and the Lincoln Laboratories of the Massachusetts Institute of Technology, has resulted in significant progress in finding and solving these problems. Still, launch of the first spacecraft (GOES-I) was not expected before early 1994. GOES-7 was expected to continue in service through 1993. To preclude possible loss of coverage for severe storms, NOAA was working on an agreement with ESA and EUMESAT for additional backup support beyond Meteosat-3 if the need arose.

A related NOAA program was **GOES-Tap**, which enabled users to acquire high-quality satellite imagery over telephone data circuits. At the end of the fiscal year, there were approximately 180 primary and over 150 secondary users of the data–notably the field forecast offices of the National Weather Service (NWS), but also the FAA and other civilian agencies (both state and federal), the DoD, private companies, universities, and the media. GOES-Tap consisted of visible, infrared, and enhanced infrared facsimile images from the GOES and NOAA satellites, plus the Defense Meteorological Satellite Program (DMSP–see below), the Japanese Geostationary Meteorological Satellite, and the European Meteosat satellites. To improve the operational utility of Meteosat-3 data, beginning in February 1992, NOAA added U.S. state grids and international boundaries to it.

During 1992, scientists within NOAA were in the process of combining satellite-derived information with climatic data observed from the surface of the Earth to better understand the influence of urbanization on long-term temperature records. Visible and near-infrared reflectance observed by NOAA's **Advanced Very High Resolution Radiometer** (AVHRR), an instrument onboard the NOAA polar-orbiting series of satellites, was providing the data for computation of an index of the presence of green vegetation within and around selected cities within the United States. Scientists computed the linear relationships between the differences among the values of the AVHRR-derived vegetation index for urban and rural regions and the differences in observed urban and rural minimum temperatures. The results may provide a globally consistent method for climatic analysis of urban areas.

Meanwhile, the operational **Global Vegetation Index** (GVI) produced by NOAA has provided a once-a-week view of the Earth's vegetation since May 1982. Derived from daily data acquired by the AVHRR, GVI had some limitations. Research efforts continued in the effort to improve the quality and use of the normalized difference vegetation index (NDVI) data in general circulation models and as direct indicators of year-to-year and regional variations in climatic conditions. Research was underway to increase the stability of long-term time series from the GVI to improve its usefulness as a climatic indicator.

In a different area of atmospheric studies, since 1974 NOAA has been providing nearly continuous coverage of the outgoing, longwave radiation (**OLR**) flux and the planetary albedo from sensors on the polar-orbiting satellites. While current OLR data derived from a single channel on the AVHRR in the thermal infrared portion of the spectrum, NOAA has developed an OLR product derived from four channels on the High-Resolution Infrared Sounder instrument. Beginning in May

1988, NOAA has computed the planetary albedo from a scene-independent, linear combination of two channels on the AVHRR and corrected for the angular dependence of the reflected radiation. NOAA will begin using new, scene-dependent algorithms in the very near future, since research has shown that they yield more accurate results. The OLR and the albedo have been extremely useful in monitoring the climatic effects of the burning Kuwaiti oil in the Persian Gulf region. Large decreases in the cloudless albedo showed up over normally bright desert sand as early as the day after the fires began. Gradually, as fire fighters extinguished the blazes, the albedo returned to more normal values. A comparison of the albedos for 1989, 1990, and 1991 showed that the values of the albedos for 1989 and 1990 were slightly higher than that for 1991.

National Environmental Satellite Data and Information Service (NESDIS) scientists were intimately involved in the **STORM-Fronts Experiment Systems Test** (STORM-FEST) that took place over the central United States during the winter of 1991-92. Prior to the experiment, NESDIS developed an improved multi-spectral imaging schedule for GOES-7 to support the field experiment. Next, the Service provided training that focused on uses of the improved multi-spectral satellite data for winter storm forecasting to the STORM-FEST major forecast centers. A special system for satellite data analysis was located in the mobile operational control center of the National Center for Atmospheric Research (NCAR) during the experiment, with scientists from NESDIS and two of its cooperative institutes, Cooperative Institute for Research in the Atmosphere (CIRA) and Cooperative Institute for Mesoscale Meteorological Studies, providing on-site expertise in satellite analysis.

With specific reference to **Tropical Cyclone Research**, Researchers at CIRA were using large observational data sets to study tropical cyclones in all regions of the world. Extensive analyses of satellite, aircraft, and conventional weather data for a large number of individual cases was underway at the end of the year. Primary research topics were the genesis, intensity, and motion of tropical cyclones. A new, two-stage conceptual model of tropical cyclone formation was one of the main findings of research focusing on tropical cyclogenesis in the western North Pacific. Those results appeared in a NOAA NESDIS technical report. CIRA provided software designed to aid in the prediction of tropical cyclone genesis to the National Hurricane Center and other users for their testing during the 1992 hurricane season. Refinements and improvements to objective techniques for diagnosis and predicting of hurricane intensity using infrared satellite analysis techniques have also been made available to operational tropical cyclone forecast centers. NESDIS scientists also used real-time GOES images to study a number of anomalous tropical events and devastating hurricanes during 1992. They monitored Hurricanes Andrew and Iniki and were using an extensive data set for retrospective analysis.

Also in the area of **Severe Storm Research**, NESDIS researchers were working with satellite data and interactive computer systems to improve forecasts of tornadoes and other types of severe weather produced by thunderstorms. CIRA developed software that allowed a user to analyze animated satellite imagery of a cloud or storm. Called a "cloud relative mode," this kind of software was very useful for severe storm diagnostics, for mesoscale wind-field determination, and for observing interactions between storms and their environments. CIRA sent the software to the National Severe Storm Forecast Center and other users for testing.

In April 1992, NOAA implemented a major improvement in the temperature and humidity product for the Television and Infrared Operational Satellite (TIROS) Operational Vertical Sounder (**TOVS**) on the polar-orbiting spacecraft. This marked the single greatest improvement in the accuracy of data from these satellites in their 13 years of operation.

A further development in the area of atmospheric science and oceanography was the signing of a memorandum of understanding on March 24, 1992, between NOAA and ESA allowing for U.S. operational access to low-bit-rate, fast-delivery data from ESA's Remote Sensing satellite, **ERS-1**, in connection with NOAA's calibration and validation support for the ERS-1 mission. ERS-1, launched as Europe's first Earth observation satellite on July 17, 1991, carries sensors that provide data on surface conditions of the global oceans and the land, sea ice, and the atmosphere–data that will be useful in the research and monitoring of global change. ERS-1 was providing the only observations that are expected to play a crucial role in international scientific cooperation on the NSF-led World Ocean Circulation Experiment and the Joint Global Ocean Flux Study, both of which were ongoing during FY 1992. In connection with a charge from the interagency Committee on Earth and Environmental Sciences (CEES) to obtain data from ERS-1 for U.S. Government operational purposes, NOAA succeeded in obtaining ESA agreement to share use of this data among other U.S. Government agencies and their contractors for research into global change.

Somewhat relatedly, the **U.S. Geological Survey** continued to organize, produce, and distribute land-related data sets to support the global change research community. Scientists used this data to quantify land surface parameters for modeling land/atmosphere interactions and ecosystem function. The Survey also continued developing prototype Earth science data sets required for land process studies.

Remote sensing of the oceans by satellite continued to play an important role in **National Marine Fisheries** research. Satellite observations provide the synoptic information needed for studying the effects of the ocean environment on the abundance and distribution of fish populations. As but one example among many that could be mentioned, by the end of the fiscal year the Alaska Fisheries Science Center's scientists had developed and deployed 14 fully operational satellite tracking systems that monitored movements of several hundred radio-tagged adult salmon returning in 1992 to a remote transboundary river system flowing through Canada and Alaska. The information, relayed by satellite, on migration timing and the distribution of stocks permitted U.S. and Canadian scientists to design joint management strategies required by the Pacific Salmon Treaty.

In a very different kind of application for satellite technology, the **Defense Meteorological Satellite Program** provided timely, high quality, worldwide, visible and infrared cloud imagery and other specialized environmental data to support the DoD's strategic missions. The system also provided real-time, direct-readout data on the local environmental conditions in particular areas to ground- and ship-based users worldwide. To meet the ongoing needs of these users, the first of the improved Block 5D-2 satellites launched on an Atlas E on November 28, 1991, from Vandenberg AFB, CA. This satellite achieved a near-perfect orbit and began operations 11 days ahead of schedule in December 1991. The sensor complement on this satellite includes the first water vapor profiler placed in orbit. This sensor provides information on the vertical humidity profile and water vapor content on a global basis. Calibration and validation of the sensor and the associated processing software has proceeded throughout 1992. The initial results show favorable comparison of the satellite moisture profiles with the atmospheric profile from worldwide balloon-borne instruments.

To meet the pressing needs of a deployable versus deployed force, progress continued on the upgrade to tactical terminal capabilities. The upgrade from 1970s to early 1990s technology, the MarkIVB, successfully completed operational testing in May 1992. This led, in June 1992, to a production decision for the first six terminals. This system will significantly increase the capability of the theater-level user to capture data from DMSP as well as civilian satellite systems. Fixed and transportable configurations, with first delivery in 1994, will give the weather forecaster first-ever access to all the mission sensor data from DMSP that is critical to determining the state of the atmosphere, the ocean, and the land surface. This information is vital to determining environmental effects on sophisticated weapon systems and in assessing the direction and intensity of tropical storms and hurricanes. An additional effort–to reduce the ground receiver terminals to a size that a single person can carry–was underway at the end of the year, with an initial contractor effort scheduled to begin in January 1993. This system, the Small Tactical Terminal, will gather low-resolution data from DMSP and civilian satellites in a package needed by highly mobile combat forces.

The DMSP program was also instrumental, in cooperation with several civilian agencies, in establishing the first complete, digital archive of weather data. These data will be available to DoD, Government, civilian agencies, and universities to enhance environmental research activities related to such issues as global changes in the climate.

In a related area, the **Geodetic/Geophysical Follow-on** (GFO) satellite program, the Navy awarded a contract that will lead to the launch of an operational radar altimeter satellite in support of tactical oceanography. The contract provides for the first satellite to be launched in late 1995, with up to two additional satellites as needed to provide the Navy an operational capability until a radar altimeter can be placed aboard the DMSP satellites. GFO will provide timely, worldwide, and extremely accurate measurements of ocean topography via direct read out to ships at sea and selected shore sites. GFO will also store data on-board and provide full orbital coverage to the Naval Oceanography Command's primary numerical forecasting centers. The direct-read-out data will enhance on-scene tactical support, with forecasting centers using the stored data to improve the performance of ocean circulation models.

Other Aeronautical and Space Activities

Discussions Concerning Arms Control of Space Related Weaponry

As of the beginning of FY 1992, the United States had been engaged for many years in bilateral negotiations with the Soviet Union in the Nuclear and Space Talks. As part of those talks, the U.S. side proposed building a more stable strategic regime by introducing defenses against strategic ballistic missiles, although the Anti-Ballistic Missile Treaty with the Soviet Union in 1972, as modified in 1974, had limited antiballistic missiles to one site in each country. During 1989-91, Communist rule in Eastern Europe ended, the Soviet Union dissolved, and the Cold War ended. As a result, we are now discussing with Russia the concept of a **Global Protection System** against limited ballistic missile strikes.

Key steps in this evolutionary process began when U.S. President George Bush refocused the Strategic Defense Initiative (SDI) program in January 1991 toward protection against limited ballistic missile strikes, whatever their source. This change reflected not only an improving relationship with the Soviet Union but also an acknowledgement that the nature of the threat was changing due to the proliferation of ballistic missiles around the world. In January 1992, President Boris Yeltsin of Russia called for a global system for protection of the world community that could be based on a reorientation of the U.S. SDI to make use of, in his words, "high technology developed in Russia's defense complex." In February 1992, U.S. Secretary of State James A. Baker told President Yeltsin in Moscow that the United States welcomed his proposal for a global ballistic missile defense system.

This new U.S.-Russian cooperative approach has unfolded further in a series of meetings in 1992. In a Joint Statement issued by Presidents Bush and Yeltsin on June 17, 1992, at their Washington Summit meeting, they stated that they had continued their discussion of the potential benefits of a Global Protection System against ballistic missiles, agreeing that it was important to explore the role for defenses in protecting against limited ballistic missile attacks. The two Presidents agreed that their nations should work together with allies and other interested states in developing a concept for such a system as part of an overall strategy regarding the proliferation of ballistic missiles and weapons of mass destruction. To this end, they agreed to establish a high-level group to explore on a priority basis: (1) the potential for sharing of early warning information through the establishment of an early warning center; (2) the potential for cooperation with participating states in developing ballistic missile defense capabilities and technologies; and (3) the development of a legal basis for cooperation, including new treaties and agreements and possible changes to existing treaties and agreements necessary to implement a Global Protection System.

U.S. and Russian delegations met in Moscow on July 13-14, 1992, during which they established three working groups. The Russians were aware of the U.S. view that changes in the security environment, including the break-up of the Soviet Union and the proliferation of ballistic missiles, require us to update the Anti-Ballistic Missile (ABM) Treaty of 1972. Further meetings of the delegations took place on September 21-22 in Washington. The two nations agreed to work together to meet the security challenges of the future as partners and friends. In the face of dangers from weapons of mass destruction, they discussed potential benefits of a Global Protection System. These discussions were continued, with separate working groups meeting in October 1992. In addition to these discussions with Russia, the United States has been meeting with allies and other nations who might benefit from the security provided by such a protective system.

In FY 1992, the U.S. Arms Control and Disarmament Agency (ACDA) participated in multilateral discussions on outer space arms control at the **Conference on Disarmament** and at the United Nations First Committee. Though these discussions were informative in providing a venue for the participation of non-space powers, neither the United States nor any other party has been able to identify any outer-space arms control issues appropriate for multilateral negotiations. The United States again supported at the Conference on Disarmament the formation of an appropriate, non-negotiating, ad hoc committee to consider issues relevant to space arms control. While discussions enhanced understanding, issues appropriate for multilateral negotiations were not, in the U.S. view, identified.

The First Committee of the **United Nations** General Assembly met from October through November 1991 and considered one draft resolution on outer space. The United States abstained on this measure primarily because it called for negotiations at the Conference on Disarmament on measures to "prevent an arms race in outer space." As a result of a United Nations resolution adopted in 1990, the Secretary General directed a study on confidence-building measures in outer space. He expected to report its results at the 47th session in 1992. While the United States abstained on that resolution because of the financial implications, it was participating in the study.

Relatedly, the **Missile Technology Control Regime** (MTCR), an informal group of like-minded countries, organized itself in April 1987 to control missiles and technology that could contribute to unmanned systems capable of delivering nuclear weapons. Since space launch vehicle (SLV) technology is essentially identical to that used in missiles, SLV technology was subject to the same controls as was missile technology. The war with Iraq in 1991 made clear to the entire world that the time had come to increase the effectiveness of controls on missiles capable of delivering chemical and biological weapons. Accordingly, the MTCR partners, at their June 1992 Plenary in Oslo, broadened the scope of MTCR to cover "all weapons of mass destruction"–i.e., chemical and biological as well as nuclear weapons. Since chemical and biological weapons can be packaged in lighter warheads than nuclear weapons, MTCR controls will be applied to smaller, lighter missiles and SLVs. In effect, all exports of missiles and SLVs, regardless of payload, will need to be controlled under the revised guidelines.

Following the March 1992 White House announcement of a new, more open and cooperative space relationship between the United States and the Commonwealth of Independent States (CIS–the organization formed by 9 of the former 11 Soviet Republics), contacts between the U.S. Government and its private sector, on the one hand, and their counterparts in the CIS, particularly Russia, on the other, increased rapidly. One of the priority U.S. objectives in this regard has been to find commercial employment for CIS weapons scientists and engineers. The United States has taken the lead in establishing science and technology centers in Moscow and Kiev that will perform this function. Because of the concentration of missile and SLV activities in the Ukraine, the Kiev center will focus on finding alternative employment for missile scientists. The U.S.-Russian space relationship will also be affected by considerations of missile nonproliferation. The Russian firm Glavkosmos has contracted to supply the Indian Space Research Organization with cryogenic rocket technology for use in the Indian SLV program, which is closely tied to the Indian missile program. The United States and other MTCR partners consider this transaction a violation of MTCR standards. Consequently, the United States, acting in accordance with U.S. law, imposed trade and contract sanctions on both Glavkosmos and the Indian Space Research Organization.

Cooperation with the Former Soviet Union

On a much more positive note, the Presidents of the United States and Russia signed a new agreement on space cooperation at the June 1992 Washington Summit (see Appendix F-4). The Department of State (DOS) coordinated the preparation and negotiation of the agreement, which put space cooperation on a new footing, providing the foundation for expanded opportunities in scientific exploration and the commercial application of space technology. The agreement provides a broad framework for the U.S. and Russia to pursue new projects in a full range of fields, such as space science, space exploration, space applications, and the use of space technology. An important part of the agreement involves annual subcabinet consultations led on the U.S. side by the Under Secretary of State for International Security Affairs and on the Russian side by the Deputy Foreign Minister. This will provide a new mechanism for high level Government review of the bilateral civil space relationship between the two countries.

At the Summit, the two sides also agreed to flights of a Russian cosmonaut or cosmonauts aboard a space shuttle mission in 1993 and a U.S. astronaut or astronauts aboard the Russian Mir space station in 1994, plus a rendezvous and docking mission between Mir and the space shuttle in 1995. The two Governments would pursue detailed technical studies of the possible use of space technology. NASA awarded a contract to the Russian firm NPO Energiya to examine the use of the Russian Soyuz-Tm spacecraft as an interim crew rescue vehicle for Space Station Freedom. Other important areas to be studied are the suitability of the Russian-developed Automated Rendezvous and Docking System in support of NASA spaceflight activities, the use of Mir for long-lead-time medical experiments, and other applications by NASA of Russian hardware. For NASA, the Office of Space Flight (Russian Affairs) assumed the responsibility for managing the NASA portion of the Cooperative Human Space Flight Programs with the Russian Space Agency for the missions mentioned above. Following the Summit, the NASA Administrator and the National Space Council Executive Secretary led a team of U.S. space experts to Russia in July. They made significant progress in developing a plan to carry out the projects outlined above.

Later that month, the Department of Commerce conducted a space technology assessment to Russia. The purpose of the trip was to allow technical representatives of U.S. industry to gain first-hand knowledge of the capabilities of the Russian space industry. The Office of Space Commerce led the mission, which included representatives of the DoD, DoT, DoE, NASA, and 17 U.S. companies. In cooperation with the Russian Space Agency and the Russian Ministry of Industry, the mission visited 25 aeronautical and space-related facilities around Moscow and St. Petersburg.

Other Foreign Policy Issues

In other negotiations during 1992, the **U.N.'s Committee on the Peaceful Uses of Outer Space** (COPUOS) and its subcommittees–with the DOS, supported by NASA, DoD, DoC, and DoE, responsible for U.S. participation–pursued an ambitious program of activities commemorating the U.S.-proposed International Space Year (ISY). Also, after many years of negotiation, COPUOS and its Legal Subcommittee concluded work on a set of non-binding principles on the use of nuclear power sources in space and recommended that they be adopted by consensus at the 1992 session of the General Assembly. The principles deal with the public availability of safety assessments for each launch of a nuclear power source into space, each member state's responsibility in the event of an unplanned re-entry, notification and the provision of assistance in the event of an accident, and compensation for damage caused by such a nuclear power source. Although non-binding, these principles represent an important international statement on how sources of nuclear power can be used safely for the exploration of outer space.

During FY 1992, the **Space Shuttle** task force activated to support the seven missions described above. It provided direct links to U.S. embassies in countries where emergency landing facilities were located. DOS in coordination with NASA provided all posts with general procedures to be followed in the unlikely event the Shuttle had to abort a mission and make an emergency landing outside the continental United States. The Department ensured local country plans were developed, exercises conducted, and all other necessary planning was up to date in the event of such an emergency. It also participated in a first-ever coordinated NASA, U.S. Space Command, and State Department exercise to evaluate Space Shuttle Emergency Support Operations (Apollo Griffin).

Meanwhile, in November the Secretaries of State and Commerce jointly sent a letter to the FCC informing it of an Executive Branch policy to expand competition in **International Satellite Services**. Private, non-INTELSAT international satellite networks (often called "separate systems") would be allowed significant new opportunities to route their customers' communications over the public-switched (telephone and telex) networks. The Executive Branch also stated its desire to have unfettered international satellite competition before 1997. This policy change focused on competition with INTELSAT in the provision of fixed satellite services (to stationary Earth stations) as opposed to competition in mobile satellite services (to mobile terminals).

In 1992, the second private U.S. fixed-satellite system, Columbia Communications, began operation using spare capacity on two NASA Tracking and Data Relay satellites. Columbia began providing both transatlantic and transpacific service. The American operator of the first private intercontinental system, Pan American Satellite, continued to expand its operations and make plans to augment its system. Its first satellite had been in continuous orbit since 1988 as the year ended. Often with help from various executive branch agencies, both of these companies have succeeded in gaining authority from several additional countries to provide service within their borders. International users of satellite services have already realized benefits of new services and lower prices.

In recognition of the inevitability of competition (particularly from undersea fiber-optic cables) and the waste involved in treaty-mandated, *pro forma* reviews of traffic projections supplied by satellite competitors, this year INTELSAT completed its second major review of Article XIV(d) of the INTELSAT agreement. This required that INTELSAT member countries intending to use "space segment facilities separate from INTELSAT" had first to "consult" with the Assembly of Parties, a meeting of all 124 member countries. The convening of such a meeting to review what were, at best, rough projections of a single market player, was both a waste of time and resources for INTELSAT and an unfair burden on potential competitors. Led by the State Department, the Commerce Department, the FCC, and the U.S. signatory to INTELSAT (the Communications Satellite Corporation) together were instrumental in convincing INTELSAT's Board of Governors to recommend to the Assembly of Parties that this anachronism of an age when satellite technology was unproven be significantly streamlined with a view towards its total elimination. The Assembly was scheduled to meet in November 1992 to consider these recommendations.

Meanwhile, the dramatic retrieval and reboost of the INTELSAT VI (F-3) already described was a vivid capstone of successful cooperation between several U.S. agencies, private companies, and INTELSAT. NASA, INTELSAT, and Hughes Aircraft (the satellite's manufacturer and supplier of the reboost motor) shared the bulk of the credit for this history-making mission that captivated the world. Other agencies played roles as well. The State Department frequently served as an interface between INTELSAT and other mission participants as preparations proceeded.

Pursuant to recommendations from the 8th INMARSAT Assembly of Parties in September 1991, INMARSAT Parties and Signatories created an Intersessional Working Group to consider the future shape of the international organization. The Group began work in November 1991, meeting in conjunction with each Council meeting. It will offer a report to the 9th Assembly of Parties in October 1993. In its two meetings during FY 1992, the Working Group focused on the INMARSAT Convention's Article 8 "notification" procedure, which required competing satellite systems to present their proposed maritime services to INMARSAT for review before beginning service. In July 1992, the Group decided to recommend to the 9th Assembly that it make an *"a priori"* determination that competing systems would not cause significant economic harm to the INMARSAT system. Such a determination would shorten and simplify considerably the INMARSAT notification process.

As an adjunct to the Intersessional Working Group (IWG), the INMARSAT Council created a Council Working Group (CWG) to report to the IWG on the commercial, operational, and organizational arrangements of INMARSAT. The CWG examined a variety of issues–including questions of financing, governance, and access to the INMARSAT space segment–and compiled its views into a final report. The IWG received this report in July 1992 and planned to use it as a primary input document for IWG deliberations in late 1992 and 1993.

Operating under the rules established by the 8th Assembly, the INMARSAT Council decided to delegate to the Director General its authority to determine if "notified" separate systems will cause technical interference with the INMARSAT system. In separate decisions, the Council made non-binding recommendations to the Assembly offering no objection to maritime services to be provided by American, Japanese, Norwegian, and common European satellites.

The INMARSAT Directorate and Signatories began consideration of the economic viability of and technical options for a proposed global handheld telecommunications system called Project 21, a family of personal mobile satellite communications services, including INMARSAT-P. Participants held an annual meeting in January 1992, with a project review meeting scheduled for October 1992. The Directorate anticipated that the Council 44 meeting in November 1992 would be able to begin a formal review of all technical and economic factors bearing on a future decision about Project 21.

Meanwhile, the INMARSAT Council was unable to reach a consensus on a policy regarding lease of unused space segment. Council members split between a view that this space segment was an untapped resource capable of generating profit and a fear that leasing it would encourage the growth of competitors to INMARSAT. The U.S. signatory favored a policy permitting leases both as a means of maximizing revenue and as a way to retain customers who might otherwise switch to a competing system. Council 44 will reconsider the issue in November.

With the breakup of the former Soviet Union, the Russian Federation assumed the INMARSAT Council seat formerly held by the USSR. Belarus and the Ukraine stated their intention to remain Parties. As the year ended, the three nations were examining how to apportion the USSR's investment share in INMARSAT. Meanwhile, Cyprus joined INMARSAT in June 1992, becoming the 65th member state. Also, in March 1992, Australia, India, and Korea administratively joined their investment shares to create a share percentage meriting group representation on the INMARSAT Council.

Finally, in July 1992, the INMARSAT Council approved provision of INMARSAT C data/message service to aeronautical users. Aero-C will not provide distress call service as does standard INMARSAT C to maritime users, because Aero-C was not designed for safety and regularity of flight service.

A further area where foreign relations and space intertwined was in the continuing effort to understand and protect against orbital debris. Based on their **Orbital Debris** Coordinating Meetings held biannually since 1989, NASA and ESA continued to pursue a strong cooperative effort on the subject. On August 17, 1992, NASA and ESA finalized a letter agreement documenting the common interest shared by the two agencies in continuing their joint efforts in the area of space debris. NASA has also signed letter agreements with the French and German space agencies and has held regular coordination meetings on the subject with Japanese, Russian, and Chinese officials. As a result, subsequent to a NASA presentation on the explosion of a Long March upper stage, the Chinese have modified their vehicles to prevent such future explosions. On the multilateral front, NASA participated in a working group of the International Consultative Committee for Radio, which recommended in May 1992 that a "graveyard" orbit be established at least 300 kilometers above geosynchronous Earth orbit for the purpose of disposing of satellites at the ends of their operational lives. The full committee will be considering the adoption of this recommendation.

In still **Another Area of International Relations**, the U.S. Trade Representative led negotiations with ESA and the European Community to establish "rules of the road" for international commercial space launch services. Efforts focused on defining types of Government supports and subsidies to prevent unfair competition. There were also consultations with the People's Republic of China in Washington and Beijing on the U.S.-PRC Launch Services Agreement. This allows China to launch up to nine western satellites over six years subject to certain conditions. The U.S. and Chinese Governments discussed pricing and other business practices. The Agreement is due to expire in 1994. Finally, as part of the June Summit, the President announced a one-time exception to the U.S. policy of barring Western-made satellites from being launched on Soviet-derived boosters. The exception was designed to allow Russia to compete for the launch of one satellite from the INMARSAT organization. In conjunction with this exception, the United States and Russia entered into discussions on commercial launch services and held meetings in Washington and Moscow. These discussions were aimed at allowing some Russian participation in international launch competitions while avoiding harmful disruptions by nonmarket practices.

International Conferences

FY 1992 featured several important international meetings and conferences, including notably the International Telecommunication Union's (ITU) **World Administrative Radio Conference** (WARC 92), which met from February 3 to March 3, 1992, at Torremolinos, Spain. The conference was attended by more than 1,400 delegates from 127 of the ITU's 166 member nations plus observers from 32 international and regional organizations. Its purpose was to establish and revise rules and regulations governing spectrum-related telecommunications services worldwide. NASA spoke on behalf of the United States on issues related to frequencies above 3 gigahertz; it held several preparatory meetings and participated in the conference itself, as did the FCC and the National Telecommunications and Information Administration (NTIA) as well as other Government agencies. The changes decided at WARC 92 were numerous and complex. The conferees reached agreements on most issues as a result of compromises following extensive negotiations. The United States was able to secure worldwide frequency allocations that will enable low Earth orbiting satellites to be employed in providing global telecommunication services including paging, data transfer, and voice services. WARC allocated new frequencies that may be used by Space Station Freedom, the space shuttle, astronauts engaged in extravehicular activities, TDRS II, and the Space Exploration Initiative. It also approved NASA proposals to improve the status of the most used frequency bands, near 2 gigahertz; upgraded the status of several allocations used to communicate with deep space probes; extended frequency bands used for shortwave broadcasting; made several primary and secondary allocations for the Mobile Satellite Service, some worldwide and some regional, in frequencies between 1 and 3 gigahertz; and provided frequency allocation for broadcasting satellite services for direct audio broadcasting from space and transmission of high-definition television signals by satellite. The U.S. space service proposals to WARC met with considerable success, due primarily to years of detailed preparations and coordination within the Space Frequency Coordination Group.

In late August 1992, Washington D.C. was the site of international meetings marking the International Space Year. The **Space Agency Forum of the International Space Year**, which brought together representatives of space agencies and associated organizations from around the world to develop ISY projects in Earth science, space science and education, held its fifth and final annual meeting. The SAFISY members decided to establish the Space Agency Forum to promote continued international space cooperation. Immediately after the SAFISY meeting, the World Space Congress brought over 5,000 participants to the city for extensive exchanges of technical, scientific, and policy information on space. The Congress, a joint meeting of the International Astronautical Federation and the Committee on Space Research, was organized by the American Institute of Aeronautics and Astronautics, with financial sponsorship from NASA.

Regulation of Commercial Space Industries

In December 1991 the FCC approved the first commercial use of the C-band satellites leased by Columbia from NASA on the TDRSS satellites located at 41 degrees West Longitude and 174 degrees West Longitude. The Commission has also authorized three companies to experiment with small, low Earth orbiting satellites for communications purposes. Volunteers in Technical Assistance has been so authorized since November 1990. Orbital Sciences Corporation modified its existing authorization in March 1992 to comply with the newly allocated WARC 1992 frequency bands for small, low Earth orbiting satellites. The FCC also granted an experimental license on April 3, 1992, to Starsys Global Positioning, Inc. to conduct simulation experiments using a balloon with a transponder.

On July 20, 1992, the FCC authorized Afrispace, Inc. an experimental license for the construction, launch, and operation of a geostationary satellite that will provide Broadcasting Satellite Sound services to Africa and the Middle East. The satellite will operate in the newly allocated Broadcasting Satellite band 1467-1492 megahertz. It will be located at 12 degrees West Longitude and will provide informational, health, educational, scientific, and cultural programming to this region.

Then on August 5, 1992, the FCC authorized four companies to conduct experiments involving low Earth orbiting satellites operating above the frequency of 1 gigahertz. Motorola Satellite Communications Inc. received authorization for five satellites and associated ground stations; Constellation Communications, Inc., for two satellites and associated ground stations; Ellipsat Corporation, for four satellites and associated ground stations. TRW Corporation also got an experimental license, but only for simulation of satellites by use of aircraft and balloons.

Commercial Development of Space Technology

As part of its program to encourage private sector involvement and investment in new, high-technology, space-related products and services, in November 1991, NASA's Office of Commercial Programs (OCP) established two new **Centers for the Commercial Development of Space** (CCDS) to specialize in advanced satellite communications and other space-based telecommunications technologies. The Space Communications Technology Center at Florida Atlantic University, one of the two new centers, is devoted to developing the technologies required for digital transmission by satellite of video, audio, and other data. With Motorola, Inc., as its industrial partner, the Center is developing the Low Earth Orbit Experiment (LEOEX) to enable experimental testing and demonstration of some of the key technologies needed to achieve point-to-point voice and data communications via satellites in low Earth orbit. The payload was scheduled to be launched in mid-1993 on the Commercial Experiment Transporter, which will consist of an experimental capsule that will remain in orbit for weeks or months before returning to Earth and another capsule that will stay in orbit longer.

The other CCDS, the Center for Satellite and Hybrid Communication Networks at the University of Maryland Systems Research Center, focuses on hybrid networks and the integration of terrestrial and space communications technologies. Together with COMSAT Labs, the Center was building a frame relay interface to the Very Small Aperture Terminal on the Advanced Communications Technology Satellite (ACTS), scheduled for launch in 1993. These two new centers brought the total number in the CCDS program to 17 at the end of the fiscal year.

The purpose of **ACTS** is to demonstrate new technologies for communications satellites. In the summer of 1992, NASA selected 31 experiments (from 50 proposals) in response to an announcement in 1991 of experimental opportunities. These experiments–and the ACTS program–should assist in defining communications requirements for the next generation of communications satellites. In April 1992, NASA selected 10 ACTS propagation experiments out of 30 proposals received in response to a 1991 NASA Research Announcement. These experiments will serve as a means of understanding the propagation environment for an uplink frequency of 30 gigahertz and a downlink frequency of 20 gigahertz, which telecommunications companies are interested in using for future satellite communications systems.

In another area, OCP has co-funded 12 projects with industry in the second round of the **Earth Observation Commercial Application Program,** which began in the fall of 1991. The program promotes the development of new or improved products and services in the area of remote sensing. It has already yielded applications in oil spill mapping, fisheries and forest resource management, agricultural monitoring, urban land use, hazardous waste detection, and real-time damage assessment of natural disasters.

In a rather different application of space technology, researchers at George J. Igel and Company and the Ohio State University's Center for Mapping, another NASA CCDS, have co-developed a precise positioning system for earth-moving equipment. Using **GPS** receiver antennae and software that integrates GPS positional data with surface data, the system permits immediate adjustments to land irregularities, thus saving manpower and reducing operational costs. The CCDS also launched a private company in 1991 named Real-Time Mapping Systems, Inc. The firm constructs commercial GPS mapping vehicles for use in road planning, and it has recently sold its second generation GPS vehicle to a Canadian engineering and survey firm.

While most CCDS technologies were still in the experimental phase at the end of FY 1992, there had already been significant results in materials processing and biotechnology. For example, space experiments have shown that **Protein Crystals** grown in space to study the molecular structure of pharmaceuticals are more suitable for such analysis than crystals grown on Earth. The reasons for this phenomenon are complex, but generally, materials mix more evenly in space, fluids form perfectly round spheres, and pure crystals grow larger because there is so little gravity. Researchers have already reported that 40 percent of the proteins flown on the STS-50 Shuttle mission in June produced larger and higher-quality crystals than their ground-based counterparts. This compared to 20 percent on previous flights. The increase resulted from the extended growth time on this 14-day mission and the involvement of Payload Specialist Dr. Larry DeLucas from the CCDS at Birmingham, AL, who assisted in the set-up and optimization of the experiments.

USML-1 on STS-50 also included the **Astroculture** payload–a test of a plant growing system for the zero-gravity space environment, sponsored by the Wisconsin Center for Space Automation and Robotics. The payload team reported the experiment to be a success, performing activities beyond original plans. The findings are expected to provide significant new data needed to verify the performance of a water and nutrient delivery system for plants in space, an enabling technology for long-duration human flights and for new efficiencies in Earth-based hydroponics.

The **Investigations into Polymer Membranes** payload (IPMP) completed three more space shuttle flights in FY 1992, continuing to find significant improvements in the size and distribution of the pores in the membrane filters processed. These characteristics are important factors in the ability of membranes to filter and separate substances in commercial applications. The sponsor, Battelle of Columbus, OH, has filed for a patent on the process. The circulation of information on the subject was resulting in more interest by U.S. industry in polymer investigations and processing in space.

In November 1991 EER Systems, Inc., successfully launched and recovered a Starfire sounding rocket, **Consort 4**, which provided 7 minutes of microgravity to a variety of materials processing and biological experiments (including IPMP) coordinated by the Huntsville CCDS. This was the final launch in a series of Consort flights beginning in 1989, funded by OCP. NASA awarded a follow-on contract for three launches to EER Systems in the fall of 1991. The company launched the first of them, Consort 5, in September 1992 (see above).

This contract marked only part of NASA's continued strong support to the domestic **ELV** industry under the authority of the Commercial Space Launch Act. During FY 1992, NASA also signed new support agreements with General Dynamics, McDonnell Douglas, Orbital Sciences, and a new entrant into the launch market, International Microspace.

In another area of commercial development, SPACEHAB, Inc., unveiled its first **Commercial Middeck Augmentation Module** in April 1992. It will add about 50 middeck lockers to the space shuttle's capacity for flight research. In support of private sector research, NASA decided to lease two-thirds of the available module volume over a six-flight profile for the CCDSs and for joint endeavor agreements. At the end of the year, payload integration was underway, keeping the module on schedule for its maiden flight on the Shuttle in April 1993.

In March 1992, DoT published Federal Register Notice 92-4, "Commercial Space Transportation; Evaluation Criteria for Issuance of Vehicle Safety Approval for the **Commercial Experiment Transporter (COMET) Reentry Vehicle System.**" COMET is a new commercial space vehicle that will return to Earth after its space mission is completed. EER Systems, one of three prime contractors on the COMET project, has proceeded with launch pad construction at Wallops Flight Facility. Preparation of the launch site, where COMET is scheduled to begin its maiden flight in mid-1993, represents a critical milestone for the program. COMET will provide commercial access to a microgravity and payload return capability for NASA's CCDSs. In a related development, NASA's CCDS at Ann Arbor, MI, and Booz-Allen & Hamilton have announced their partnership in an autonomous rendezvous and docking program that will demonstrate docking technology on-orbit about 1994, using two COMET service modules. This demonstration, to which the contractor has already made a significant financial commitment, will provide a significant step in the validation of technologies for automated satellite resupply and servicing.

Over the last two years, the CCDS at Auburn University and Maxwell Laboratories, Inc., have conducted extensive field testing for a new, compact, conversion-efficient **Power Supply**. The product can be used in industrial, medical, and space applications. Several versions have been introduced to the marketplace, and sales were expected to exceed $1 million in FY 1992.

In other efforts at commercial development, in FY 1992 NASA selected 301 **Small Business Innovation Research** (SBIR) Phase I contracts valued at $15 million and 135 Phase II awards totaling $67 million. Nearly one of every three completed SBIR projects has resulted in new technologies that were being used in commercial industry. For example, Irvine Sensors Corporation has developed techniques for stacking integrated circuits in a compact, cubic structure to miniaturize them, increase their speed, and require less power than conventional assemblies. The company has announced a joint venture with IBM that will carry its SBIR project results into commercial markets. One outcome of this venture could be an assembly the size of a sugar cube performing the functions of a motherboard in a personal computer. Two commercial applications of tunable-frequency laser SBIR projects by Schwartz Electro-Optics, Inc., include the Cobra 2000 for remote measurement of atmospheric composition, with sales so far exceeding $400,000, and the Titan-P for scientific spectroscopic measurements, which has had sales of several million dollars over the last two years. Bomed Medical Manufacturing Company has developed two related devices for non-invasive measurement of critical cardiac parameters, with sales of several million dollars a year.

In the area of technology transfer, **Regional Technology Transfer Centers** (RTTCs), established in six regions spanning the U.S., began operating in January

1992. The new centers, which replaced NASA's longstanding network of Industrial Applications Centers, reflect NASA's initiative to upgrade and restructure its technology transfer program in order to serve U.S. industry better. They offer better geographical coverage, establish linkages with the various state and local technology transfer programs, and act as technology transfer agents for all the Federal Laboratories in their respective regions. Working with the National Technology Transfer Center in Wheeling, WV, they form the core structure for the overall national technology transfer network.

Relatedly, the **National Technology Initiative** (NTI) inaugurated a series of 14 town meetings in February 1992, lasting until late 1992 and leading up to the Technology 2002 Conference scheduled for December 1-3 in Baltimore, MD. Supported by NASA and the Departments of Energy, Commerce, and Transportation, NTI seeks to promote a better understanding of private industry's opportunities to commercialize advances in Government technology.

In this connection, the Technology 2001 conference and exposition held in San Jose, CA, December 3-5, 1991, nearly doubled the attendance of the previous year's Tech 2000 conference. The 3-day event showcased work underway at more than 50 federal laboratories belonging to NASA and 10 other federal agencies. Some 183 companies and numerous universities exhibited technologies available for license or sale.

Also with respect to space technology, NASA's Stennis Space Center and the Wilmer Eye Institute at the Johns Hopkins Medical Institution have developed a **Low Vision Enhancement System** to aid the vision impaired. This was but one example of many successful transfers of technology in FY 1992. It involved NASA's image enhancement technology being applied to a highly portable unit that enhances real world images and remaps them instantly to compensate for impaired eyesight. The prototype, introduced in May 1992, constituted a basis for the addition of increasingly sophisticated vision-enhancing technology over the next several years. The first commercial version of the computer-driven goggles should be available in about three years through Triad, Inc., the industrial partner in the program. The units could provide assistance to approximately three million visually-handicapped patients.

In June, the DoC's Office of Space Commerce and NASA briefed industry on the potential role of commercial ventures in the **Space Exploration Initiative** (SEI), President Bush's challenge to establish a permanent outpost on the Moon and explore Mars. This followed a Presidential statement creating an exploration office (see Appendix F-2). In the presidential statement, the DoC was noted as the lead agency for encouraging private sector activities in support of SEI objectives. Industry identified a number of impediments to greater SEI-related commercial activity, such as inefficient Government procurement practices, conflicting technical standards between Government agencies, and lack of a clear legal regime protecting property rights in space.

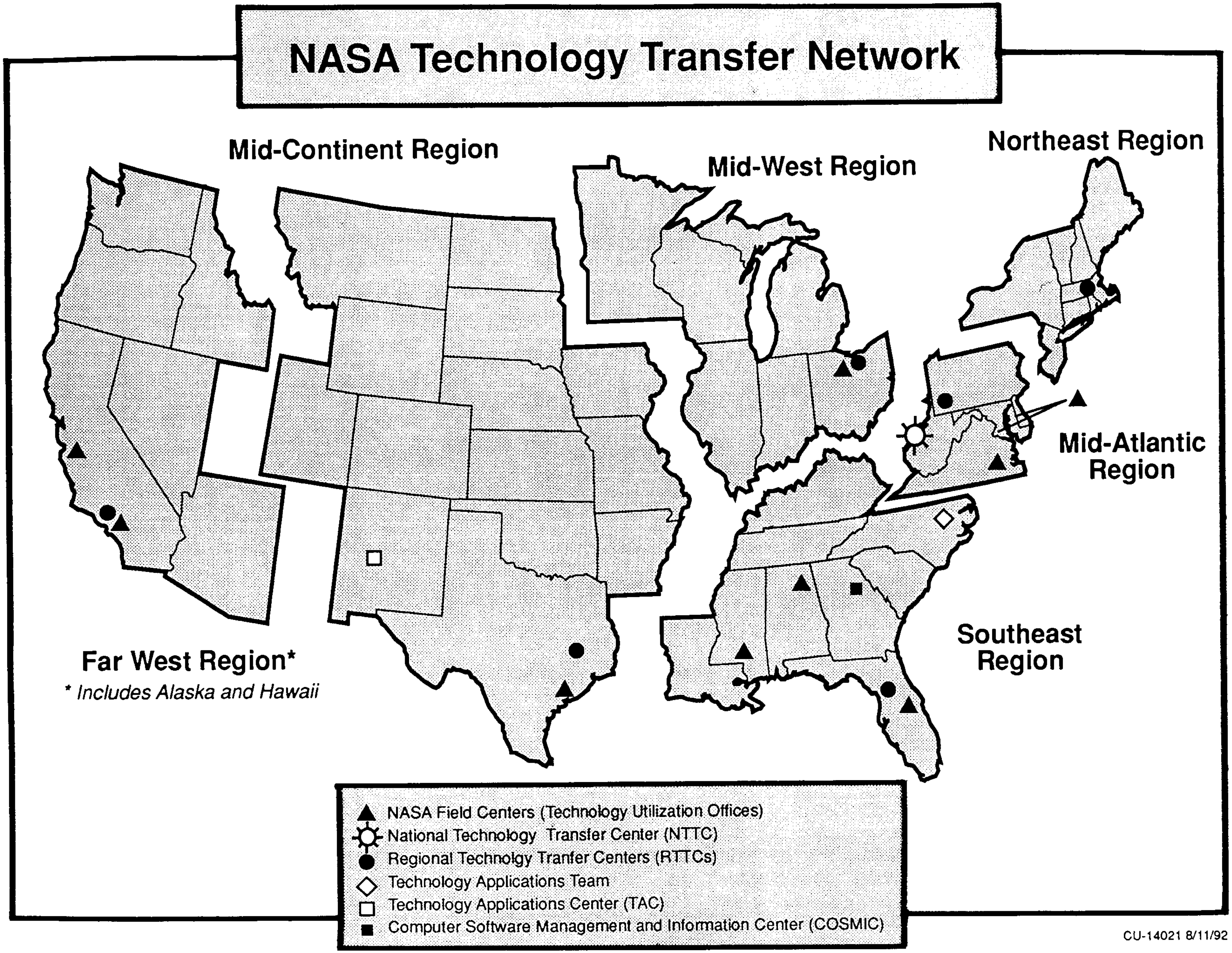
In a related area, the DoT's Office of Commercial Space Transportation administered and provided support for meetings and activities of the **Commercial Space Transportation Advisory Committee**, a 25-member group of space industry leaders. The Committee has completed a number of important studies of the industry's needs in the area of space technology, including recommendations of policies to pursue in dealing with the former Soviet Union.

Also relatedly, the DoC published the yearly edition of "**Space Business Indicators**" in June. It estimated U.S. revenues from commercial space activities at $5 billion. This represented a 14 percent increase over the previous year. Most revenues were from communications satellite sales, services, and satellite ground equipment. The fastest growing sectors were mobile telecommunications and satellite navigation receivers (e.g., those using Global Positioning System satellite signals).

Space Education and Publicity

Throughout FY 1992, several Government agencies were engaged in educating the American people about space-related activities, in publicizing them both in the United States and abroad, and in using their resources to improve American education. The best known of such activities were the enormously popular displays at the National Air and Space Museum. The U.S. Information Agency (**USIA**), on the other hand, explained U.S. space achievements to audiences abroad. It used a newly amalgamated system, Network System for TV and Radio (NETSTAR), which provided new services in the area of broadcasting, such as Direct to Affiliate Digital Service. This service carried a new program called Worldsource, which delivered programs to broadcasters in Europe for retransmission on radio stations. It included Intersputnik Direct to Affiliate Digital Service, a spin-off that reached the heartland of the former Soviet Union using a powerful satellite signal to relatively small antennas that could be deployed easily in the vast tracks of Central Asia.

The Voice of America (VOA) covered many facets of the U.S. space program in news stories, correspondent reports, and science documentaries. These features were carried in English and 46 other languages to audiences around the globe. They included on-the-scene coverage of space shuttle launches by VOA correspondents; the "New Horizons" science documentary series, which de-


NASA Technology Transfer Network
Mid-Continent Region
Mid-West Region
Northeast Region
Mid-Atlantic Region
Southeast Region
Far West Region*
* Includes Alaska and Hawaii
▲ NASA Field Centers (Technology Utilization Offices)
National Technology Transfer Center (NTTC)
● Regional Technolgy Tranfer Centers (RTTCs)
◇ Technology Applications Team
□ Technology Applications Center (TAC)
■ Computer Software Management and Information Center (COSMIC)
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voted a quarter of its programs to space issues; and the "Communications World" documentary, which covered the NASA rescue of the INTELSAT satellite, international negotiations over satellite frequencies, and the emerging prospect of direct satellite radio broadcasting.

During FY 1992, the USIA also conducted a number of teleconference programs with foreign journalists and scientists. They dealt with such subjects as deep space and planetary exploration, the challenges of being a female astronaut, the Earth Observing System, and NASA research on greenhouse gases.

Relatedly, USIA published Dialogue, a quarterly magazine of significant thought and opinion culled from the finest U.S. magazines and journals. Published in 10 languages and distributed worldwide, it featured such items as a striking picture of the face of Venus from the Magellan space probe. USIA has also provided photographs of Shuttle flights, including the recent rescue of the INTELSAT VI satellite, at the request of overseas posts. The agency's Wireless File has highlighted several major advances in space science, notably the announcement on April 23, 1992, that the Cosmic Background Explorer had detected the seeds of the cosmic structure that may explain the formation of all stars and galaxies observed in the universe today. Altogether, the file produced over 70 news stories and features on U.S. space achievements during the fiscal year. The USIA's WORLDNET television broadcasting system, similarly, covered U.S. space efforts for foreign audiences. Its programming included 15 interactive dialogues on a host of space-related topics involving journalists and science writers around the globe.

The **OCST** was similarly active in communicating its views and policy, as well as those of the DoT, to the news media, the public, and Congress. It coordinated congressional hearings and press events and prepared informational materials about space transportation.

With a somewhat different focus, **NASA**'s Education Program continued in FY 1992 to advance the Nation's educational goals through improving the scientific and technological competence of all students and educators. For example, NASA's precollege programs have used the NASA mission to demonstrate the integrated application of science, mathematics, technology, and related subjects. The agency's Aerospace Education Services Program, for example, has conducted workshops for educators and classroom assembly programs for elementary and secondary students, featuring aeronautics and space science equipment, principles of rocketry, space shuttle operations, and life in space. In the area of higher education, the National Space Grant and Fellowship Program, authorized by Congress in 1987, continued to serve as a means of developing a national academic network with greater abilities to respond to present and future aerospace needs through grants and fellowships. Among NASA's technology programs, to give but one further example of the agency's educational efforts, was NASA Spacelink, a computer information service for educators and students. Its database included in FY 1992 current news about NASA missions and programs as well as informational resources dealing with NASA programs in aeronautics and space technology, space science, space exploration, and spaceflight. Also included was information about NASA educational services, available classroom materials, and software.

Somewhat similarly, **NOAA** has sought to improve scientific and mathematical education in America by encouraging the use of data from environmental satellites in the classroom. It has broadcast data directly from environmental satellites for use in teaching subjects as varied as geography, geology, physics, mathematics, English, chemistry, and even history. These "satellite direct readout data" have proved to be effective in teaching more technical subjects and enhancing technological literacy in an age when the marketplace and society in general are assimilating new technologies at a faster rate than ever before.

Glossary

AAS	Advanced Automation System
AASE-II	Second Airborne Arctic Stratospheric Expedition
AASE	Airborne Arctic Stratospheric Expedition
ABM	Anti-Ballistic Missile
ACARS	Arinc Communications Addressing and Reporting System
ACDA	Arms Control and Disarmament Agency
ACRIM	Active Cavity Radiometer Irradiance Monitor
ACRV	Advanced Crew Return Vehicle
ACTS	Advanced Communications Technology Satellite
Ada	A programming language used by the DoD
ADAS	AWOS Data Acquisition System
ADEOS	(Japanese) Advanced Earth Observing Satellite
ADP	Advanced Ducted Propeller
AEM	Animal Enclosure Modules
AESOP	ARGOS Environmental Shipboard Observer Platform
AERA	Automated En Route Air Traffic Control System
AFB	Air Force Base
AFSC	Alaska Fisheries Science Center
AFSCN	Air Force Satellite Control Network
AFTI	Advanced Fighter Technology Integration
AFW	Active Flexible Wing
AGFS	Aviation Gridded Forecast System
AGRHYMET	AGRiculture, HYdrology, and METeorology
AIDA	Arecibo Initiative on Dynamics of the Atmosphere
AKM	Apogee Kick Motor
albedo	The ratio of the amount of electromagnetic radiation reflected by a body to the amount incident upon it
ALOHA	Airborne Lidar and Observations of Hawaiian Airglow
AMASS	Airport Movement Area Safety System
AMLS	Advanced Manned Launch System
AMOS	Air Force Maui Optical System
AMSC	American Mobile Satellite Corporation
anechoic	Neither having nor producing an echo
angle of attack	The acute angle between the chord of an airfoil and its direction of motion relative to the air, often referred to as alpha; when an airfoil's angle of attack exceeds that of the one that provides maximum lift, it goes into a stall, losing airspeed and potentially, the capability of the pilot to control the airplane
AOA	Angle of Attack
APCG	Advanced Protein Crystal Growth
APE-B	Auroral Photography Experiment-B
APM	Ascent (or Atmospheric) Particle Monitor
APT	Automatic picture transmission—a low-cost ground terminal for receiving data from polar orbiting satellites, developed by NASA
ARFF	Aircraft Rescue and Firefighting
Arinc	Aeronautical Radio, Inc
ARS	Agricultural Research Service
ARTCC	Air Route Traffic Control Center
ASAT	Anti-Satellite
ASD	Aircraft Situation Display
ASF	Area Sampling Frames
ASI	Acronym for the Italian Space Agency
ASR	Airport Surveillance Radar
ASRM	Advanced Solid Rocket Motor
ASTP	Advanced Space Technology Program; Apollo-Soyuz Test Project

Astro	Astronomy Observatory
ATLAS	Atmospheric Laboratory for Applications and Science
ATMS	Advanced Traffic Management System
AVHRR	Advanced Very High Resolution Radiometer
AWOS	Automated Weather Observing System
AXAF	Advanced X-ray Astrophysics Facility
baseband processor	A computer processor similar in function to a telephone switching office
BATSE	Burst and Transient Source Experiment
BBXRT	Broad Band X-Ray Telescope
BIMDA	Bioserve ITA Materials Dispersion Apparatus
black hole	A completely collapsed, massive dead star whose gravitational field is so powerful that no radiation can escape from it; because of this property, its existence must be inferred rather than recorded from radiation emissions.
canard	An aircraft or aircraft configuration having its horizontal stabilizing and control surfaces in front of the wing or wings
carbon-carbon	In one application, an improved form of disk brakes featuring carbon rotors and carbon stators in place of the beryllium formerly used
CASS	Computer Aided Stratification and Sampling
CAT	Clear Air Turbulence
Cassini	A Saturn Orbiter/Titan Probe
CCAFS	Cape Canaveral Air Force Station
C-CAP	CoastWatch-Change Analysis Program
CCDS	Centers for the Commercial Development of Space
CCSDS	Consultative Committee for Space Data Systems
CD-ROM	Compact Disk-Read Only Memory
CEES	Committee on Earth and Environmental Sciences
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFD	Computational Fluid Dynamics
CGMS	Coordination Group for Meteorological Satellites
CEDAR	Coupling, Energetics, and Dynamics of Atmospheric Regions
CELLS	Controlled Ecological Life Support System
CEOS	Committee on Earth Observations Satellites
CEPS	Center for Earth and Planetary Studies
CFC	Chlorofluoro-carbon
CGF	Crystal Growth Facility
CGMS	Coordination Group for Meteorological Satellites (formerly, the Coordination of Geostationary Meteorological Satellites group)
CINC	Commander-in-Chief
CIP	Capital Investment Plan
CIRA	Cooperative Institute for Research in the Atmosphere
CIRRIS	Cryogenic Infrared Radiance Instrumentation for Shuttle
CIS	Commonwealth of Independent States, a grouping of now independent states formerly part of the Soviet Union
CITE	Cargo Interface Test Equipment
CLAES	Cryogenic Limb Array Etalon Spectrometer
CNES	Acronym for the French Space Agency
COBE	Cosmic Background Explorer
COMET	Commercial Experiment Transporter
COMPTEL	Compton Telescope
COPUOS	(U.N.) Committee on the Peaceful Uses of Outer Space
COSMIC	Computer Software Management Information Center
cosmic rays	Not forms of energy, like X-rays or gamma rays, but particles of matter
COSPAS	A Soviet satellite used for search and rescue
COSTR	Collaborative Solar-Terrestrial Science

CRAF	Comet Rendezvous Asteroid Flyby
CRDA	Converging Runway Display Aid
CREAM	Cosmic Radiation Effects and Activation Monitor
CRO	Chemical Release Observation
CRRES	Combined Release and Radiation Effects Satellite
CSA	Canadian Space Agency
CSCC	Concurrent Supercomputing Consortium
CTAS	Center-TRACON Automation System
CTR	Civil Tiltrotor
CTV	Cargo Transfer Vehicle
CWG	Council Working Group (of INMARSAT)
DARPA	Defense Advanced Research Project Agency
dB	Decibel
DBS	Direct Broadcast Satellite
DCS	Data Collection System
DE	Directed Energy
Dem/Val	Demonstration/Validation
DLC	Diamond-Like-Carbon
DMSP	Defense Meteorological Satellite Program—DoD's polar orbiting weather satellite system
DNA	Defense Nuclear Agency
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DoI	Department of Interior
DOLILU	Day-of-Launch I-Load-Update
DoT	Department of Transportation
DSCS	Defense Satellite Communication System
DSN	Deep Space Network
DSP	Defense Support Program
DST	Defense and Space Talks
ECS	EOSDIS Core System
EDFE	EVA Development Flight Experiments
EDMS	Emissions and Dispersion Modeling System—an EPA-approved computer model for the assessment of air quality around airports
EDO	Extended Duration Orbiter
EDOMP	Extended Duration Orbiter Medical Program
EFM	Enhanced Fighter Maneuverability
EGRET	Energetic Gamma Ray Experiment Telescope
EHF	Extremely High Frequency, between 30,000 and 300,000 megacycles per second
electromagnetic spectrum	A collective term for all known radiation from the shortest-waved gamma rays through x-rays, ultraviolet, visible light, infrared waves, to radio waves at the long-waved end of the spectrum
ELV	Expendable Launch Vehicle
EMAP	Environmental Monitoring and Assessment Program
EMSL-LV	Environmental Monitoring Systems Laboratory in Las Vegas, NV—part of the EPA
enthalpy	The heat content of a system undergoing change
envelope	The operational parameters within which an aircraft can fly
EO-ICWG	Earth Observations-International Coordination Working Group
EOS	Earth Observing System—a series of satellites, part of the Mission to Planet Earth, being designed for launch beginning near the end of the decade to gather data on global change
EOSDIS	EOS Data and Information System
EOSAT	Earth Observation Satellite Company

EPA	Environmental Protection Agency
EPIRB	Emergency Position-Indicating Radio Beacons
EPM	Enabling Propulsion Materials
EPRI	Electric Power Research Institute
ERBE	Earth Radiation Budget Experiment
EROS	Earth Resources Observation System
ERS	European Space Agency Remote Sensing Satellite
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
E-scan	Electronically scanned
EUMESAT	European Meteorological Satellite Program
EURECA	European Retrievable Carrier
EUVE	Extreme Ultraviolet Explorer
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FAEED	FAA Aircraft Engine Emissions Database, which contains emissions factors for various aircraft engines and data correlating engines to specific aircraft
FAS	Foreign Agricultural Service
FASA	Final Approach Spacing Aid
FAST	Fast Auroral Snapshot
FCCSET	Federal Coordinating Council on Science, Engineering, and Technology
FDF	Flight Dynamics Facility
Floquet theory	A method of solving a second-order differential equation
FLTSATCOM	Fleet Satellite Communications System
FRED	FAA Research Electromagnetic Database
FSAR	Final Safety Analysis Report
FSU	Former Soviet Union
FTS	Flight Telerobotic Servicer
fuel cladding	A coating designed to contain fission products released in nuclear fuel
G or g	A symbol used to denote gravity or its effects, in particular the acceleration due to gravity; used as a unit of stress measurement for bodies undergoing acceleration
galactic cosmic rays	Cosmic rays with energy levels as high as tens of billions of electron volts and velocities approaching the speed of light
gamma rays	The shortest of electromagnetic radiations, emitted by some radioactive substances
GAS	Get Away Special
GBI	Ground Based Interceptor
GCDIS	Global Change Data and Information System
GD	General Dynamics
GDR	Geophysical Data Records
GEM	Geospace Environment Modeling
geoid	The figure of the Earth as defined by the geo-potential surface that most nearly coincides with mean sea level over the entire surface of the planet's contiguous bodies of water
Geostar	A private firm providing a satellite tracking service
geostationary	Travelling about Earth's equator at an altitude of at least 35,000 km and at a speed matching that of Earth's rotation, thereby maintaining a constant relation to points on Earth
geosynchronous	geostationary
GETSCO	General Electric Technical Services Co Inc
GFO	Geodetic/Geophysical Follow-on (program)
GFS	Generic Flight System
GGS	Global Geospace Science
GGSF	Gas-Grain Simulation Facility
GHRS	Goddard High Resolution Spectrograph

GIS	Geographic Information System
GLONASS	(Soviet) Global Navigation Satellite System
glove	In relation to laminar flow control, a suction device employing tiny, laser-drilled holes to draw off turbulent air and produce a smooth (laminar) flow of air over an aircraft's wing
GMDSS	Global Maritime Distress and Safety System
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GPALS	Global Protection Against Limited Strikes
GPHS	General Purpose Heat Source
GPS	Global Positioning System
GRO	Gamma Ray Observatory
ground effect	The temporary gain in lift during flight at very low altitudes due to the compression of the air between the wings of an airplane and the ground
GSA	General Services Administration
GSFC	Goddard Space Flight Center
GTS	Global Telecommunications System
GVI	Global Vegetation Index
Hall effect	The development of a transverse electric field in a solid material when it carries an electric current and is placed in a magnetic field perpendicular to the current
HALOE	Halogen Occultation Experiment
HAPS	Hydrazine Auxiliary Propulsion System
HARV	High Angle-of-Attack Research Vehicle
HAX	Haystack Auxiliary Radar
HEAO	High Energy Astronomy Observatory
HESP	High-Energy Solar Physics
HIDEC	Highly Integrated Digital Electronic Control
high-alpha	High angle of attack
high-bypass engine	A turbo-engine having a by-pass ratio of more than four to one, the by-pass ratio being the proportion of air that flows through the engine outside the inner case to that which flows inside that case
HIRIS	High Resolution Imaging Spectrometer
HLFC	Hybrid Laminar Flow Control
HPCC	High Performance Computing and Communications
HRDI	High Resolution Doppler Imager
HSCT	High Speed Civil Transport
HST	Hubble Space Telescope
HUT	Hopkins Ultraviolet Telescope
hypersonic	Faster than 4,000 miles per hour
IBSS	Infrared Background Signature Survey
ICAO	International Civil Aviation Organization
ICBM	Intercontinental Ballistic Missile
ICE	International Cometary Explorer
IELV	Intermediate ELV
IFM	Internal Fluid Mechanics
IFR	Instrument Flight Rules
IHPTET	Integrated High Performance Turbine Engine Technology
I-Lab	(FAA) Integration and Interaction Laboratory
IMI	Inner Magnetosphere Imager
IML	International Microgravity Laboratory
IMO	International Maritime Organization
IMP	Interplanetary Monitoring Platform
INF	Intermediate-Range Nuclear Forces (Treaty)
INM	Integrated Noise Model—a computer tool for simulation of aircraft noise

INMARSAT	International Maritime Satellite (Organization)
INTELSAT	International Telecommunications Satellite (Organization)
interferometry	The production and measurement of interference from two or more coherent wave trains emitted from the same source
ionosphere	That region of the Earth's atmosphere so named because of the presence there of ionized atoms in layers that reflect radio waves and short-wave transmissions
IPMP	Investigations into Polymer Membrane Processing
IPOMS	International Polar Orbiting Meteorological Satellite Group
IR	Infrared
IRAS	Infrared Astronomy Satellite
IRT	Icing Research Tunnel
ISAC	Intelsat Solar Array Coupon
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISAS	(Japanese) Institute of Space and Astronautical Science
ISB, TW/AA	Improved Space-Based, Tactical Warning/Attack Assessment (formerly, Follow-on Early Warning System—FEWS—a successor to DSP)
ISO	International Organization for Standardization
ISTP	International Solar-Terrestrial Physics
ISY	International Space Year (1992)
ITA	Instrumentation Technology Associates
ITO	International Test Organization
ITP	Integrated Technology Plan
ITU	International Telecommunication Union, an intergovernmental organization founded in 1865 that became a specialized agency of the United Nations in 1947 and had a membership of 166 countries in February 1992
ITWS	Integrated Terminal Weather System
IUE	International Ultraviolet Explorer
IUS	Inertial Upper Stage
IV&V	Independent Validation and Verification
IWG	Intersessional Working Group (of INMARSAT)
JEM	Japanese Experiment Module
JGOFS	Joint Global Ocean Flux Study
Josephson effect	The radiative effect associated with the passage of electron pairs across an insulating barrier separating two superconductors
Josephson junction	The weak connections between superconductors through which the Josephson effects occur
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
Ka-band components	Components to receive and transmit a new, high radio frequency
KAO	Kuiper Airborne Observatory—a C-141 Starlifter at Ames Research Center, equipped with a 0.97-meter telescope
KE	Kinetic Energy
KSC	Kennedy Space Center
Ku-band	Radio frequencies in the 11-12 gigaherz range
laminar	Of fluid flow, smooth, as contrasted with turbulent; not characterized by crossflow of fluid particles
Landsat	Also known as ERTS, a series of satellites designed to collect information about the Earth's natural resources
laser	Light amplified by simulated emission of radiation—a device that produces an intense beam of light that may be strong enough to vaporize the hardest and most heat-resistant materials, first constructed in 1960
LDEF	Long-Duration Exposure Facility
LEAP	Lightweight Exo-Atmospheric Projectile
LEO	Low-Earth Orbit

LEOEX	Low-Earth Orbit Experiment
LEX	Leading Edge eXtension
LFC	Laminar Flow Control
LfA	Laboratory for Astrophysics
Lidar	Light radar
lift/drag ratio	The ratio of the lift to the drag of any body, especially an airfoil; it is the measure of the aerodynamic effectiveness of the wing or airfoil
lightsats	Light-weight satellites
LiH	Lithium hydride
LLWAS	Low Level Windshear Alert System
LOX	Liquid oxygen
low by-pass engine	A turbo-engine having a by-pass ratio of of less than four to one—see high by-pass engine
low-Earth orbit	An orbit of the Earth some 100 to 350 nautical miles above its surface
LWIR	Long-Wavelength Infrared
M	Mach number—a relative number named after Austrian physicist Ernst Mach (1838-1916) and indicating speed with respect to that of sound in a given medium; in dry air at 32 degres F and at sea level, for example, Mach 1=approximately 741 mph or 1,192 kilometers per hour
Mach	See M
MACSAT	Multiple Access Communications Satellite
magnetosphere	The region of the Earth's atmosphere where ionized gas plays an important role in the dynamics of the atmosphere and where consequently, the geomagnetic field also exerts an important influence
man-rated	Certified to transport people into space
maser	Microwave Amplification by Simulated Emission of Radiation—a device introduced in 1953 with multiple applications in physics, chemistry, radio and television communication
mbps	megabits per second
MBR	Mars Balloon Relay
MCC	Mission Control Center
MCS	Maritime Communications Subsystem
MELV	Medium ELV
MESUR	Mars Environmental Survey Mission
Meteosat	Meteorological satellite
MIDEX	Middle-Class Explorer
MILSATCOM	Military Satellite Communications
MLS	Microwave Limb Sounder
MMD	Mean Mission Duration
MO	Mars Observer
MODE	Middeck 0-Gravity Dynamics Experiment
Mode C transponder	A radar beacon receiver/transponder capable of reporting the attitude of the aircraft aboard which it is installed
MOD-RTG	Modular Radioisotope Thermoelectric Generator
MOU	Memorandum of Understanding
MPE	Mission to Planet Earth—a program developed by NASA and the world scientific community to provide scientists with data that will allow them to understand the planet as a total system and to measure the effects of the human population upon it
MSS	Multispectral Scanner Sensors; Mobile Satellite Service
MTCR	Missile Technology Control Regime
MTD	Maneuver Technology Demonstrator
NAPP	National Aerial Photography Program
NAS	National Airspace System
NASA	National Aeronautics and Space Administration

NASCAP	NASA Charging Analysis Program
NASCOM	NASA Communications System
NASDA	(Japanese) National Space Development Agency
NASM	National Air and Space Museum
NASP	National Aero-Space Plane
NASS	National Agricultural Statistics Service
Navier-Stokes (equations)	Three equations that describe conservation of momentum for the motion of a viscous, incompressible fluid; developed in the nineteenth century by French engineer Claude-Louis-Marie Navier and English physicist Sir George Gabriel Stokes, who made the final derivation of the equations
NCAR	National Center for Atmospheric Research
NCC	Network Control Center
NCDC	National Climatic Data Center
NDVI	Normalized Difference Vegetation Index
NERVA	Nuclear Energy for Rocket Vehicle Applications —a program from 1961-72 to develop a nuclear rocket for post-Apollo missions
NESDIS	(NOAA) National Environmental Satellite, Data, and Information Service
NETSTAR	Network System for TV and Radio
neutron star	Any of a class of extremely dense, compact stars thought to be composed primarily of neutrons; see pulsar.
NGDC	National Geophysical Data Center
NHC	National Hurricane Center
NIH	National Institutes of Health
NIST	(DOC) National Institute of Standards and Technology
NLS	New Launch System; also frequently rendered National Launch System
NMC	National Meteorological Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration, also the designation of that administration's Sun-synchronous satellites in polar orbit
NODC	National Oceanographic Data Center
NOS	National Ocean Service
NOx	Any of several compounds of nitrogen and oxygen, including nitrogen oxide
NSCAT	NASA Scatterometer
NSCORT	NASA Specialized Center of Research and Training
NSF	National Science Foundation
NSpC	National Space Council
NSSFC	National Severe Storms Forecast Center
NST	Nuclear and Space Talks
NTB	National Test Bed
NTF	National Test Facility
NTI	National Technology Initiative
NTIA	(DOC) National Telecommunications and Information Administration, the Federal Government's radio spectrum manager, which coordinated the use of LEO satellite networks like those for LANDSAT, NAVSTAR GPS, the Space Shuttle, and TIROS with other countries of the world
NTTC	National Technology Transfer Center
NUDET	Nuclear Detonation
NWS	National Weather Service
OCP	(NASA) Office of Commercial Programs
OCTW	Optical Communications Through the Shuttle Window
OLR	Outgoing Longwave Radiation
order of magnitude	An amount equal to 10 times a given value; thus if some quantity was 10 times as great as another quantity, it was an order of magnitude greater; if 100 times as great, it was larger by 2 orders of magnitude

OSC	(NASA) Office of Space Commerce; Office of Space Communications
OSL	Orbiting Solar Laboratory
OSSE	Oriented Scintillation Spectrometer Experiment
OSTP	Office of Science and Technology Policy
out-of-ground effect	See "ground effect"
OV	Orbiter Vehicle
PAMRI	Peripheral Adapter Module Replacement Item
PAM	Payload Assist Module
PARE	Physiological and Anatomical Rodent Experiment
PCG	Protein Crystal Growth
PEACESAT	Pan-Pacific Education and Communication Experiments by Satellite
PEM	Particle Environment Monitor
petrology	The science that deals with the origin, history, occurrence, structure, and chemical classification of rocks
piezoelectricity	The property exhibited by some asymmetrical crystalline materials that, when subjected to strain in suitable directions, develop polarization proportional to the strain
pitch-pointing	The pointing of an aircraft with respect to its pitch (its angular displacement about an axis parallel to the aircraft's lateral axis, that is, movement of the nose up or down)
pixels	Short for "picture elements," which provide image resolution in vidicon-type detectors
plasma	A gas formed when one or more negatively charged electrons escape from an atom's positively charged nucleus, creating an electrically neutral gas composed of positive and negative particles; because it is ionized, plasma interacts with electric and magnetic fields; approximately 99 percent of matter in the Universe is thought to be in the plasma state.
plasma sheet	An extensive area of low energy, ionized gases in the tail region of the magnetosphere that undergoes considerable change during magnetospheric storms
plastic media blasting	A method of removing paint from aircraft skins by propelling them with plastic beads
PLS	Personnel Launch System
PMS	Physiological Monitoring System
PRA	Probabilistic Risk Assessment
PRC	People's Republic of China
PROSPER	PROgramme SPot Et Radar (the SPOT and radar program)
PSC	Performance Seeking Control
PSCN	Program Support Communications Network
PSE	Physiological Systems Experiment
Pu-238	A Plutonium isotope
pulsar	A pulsating radio star, which is thought to be a rapidly spinning neutron star; the latter is formed when the core of a violently exploding star called a supernova collapses inward and becomes compressed togather; pulsars emit extremely regular pulses of radio waves.
PVO	Pioneer Venus Orbiter
quasar	A class of rare cosmic objects of extreme luminosity and strong radio emission; many investigators attribute their high energy generation to gas spiraling at high velocity into a massive black hole
RAH	Reconnaissance Attack Helicopter
ramjet	A jet engine with no mechanical compressor, consisting of specially-shaped tubes or ducts open at both ends, the air necessary for combustion being shoved into the duct and compressed by the forward motion of the engine
R&D	Research and Development
R&T	Research and Technology

RAWS	Remote Automatic Weather Station
RCRA	Resource Conservation and Recovery Act
Resin Transfer Molding	A process for the fabrication of composite parts for aerospace vehicles in which a dry preform of reinforcements is placed in a mold, resin is infused by vacuum or pressure, and the part is cured in the mold
resolution	With reference to satellites, a term meaning the ability to sense an object; thus, an 80 meter resolution indicates the ability to detect an object of at least 80 meters in diameter
REX	Radiation Experiment
Reynolds number	A nondimensional parameter representing the ratio of the momentum forces in fluid flow, named for English scientist Osborne Reynolds (1842-1912); among other applications, the ratio is vital to the use of wind tunnels for scale-model testing, as it provides a basis for extrapolating the test data to full-sized test vehicles
RFI	Request for Information
RFP	Request for Proposal
RME	Radiation Monitoring Equipment
RMP	Rotorcraft Master Plan
RMS	Remote Manipulator System—a remotely controlled arm, developed by Canada and controlled from the orbiter crew cabin, used for deployment and/or retrieval of payloads from the orbiter payload bay
ROSAT	Roentgen Satellite
Rover	After 1955, a program to develop a nuclear rocket, renamed NERVA in 1961
RTG	Radioisotope Thermoelectric Generator
RTTC	Regional Technology Transfer Center
SAIN	Satellite Applications Information Notes
SAM	Shuttle Activation Monitor
SAMPEX	Solar, Anomalous, and Magnetospheric Particle Explorer
SAMS	Space Acceleration Mapping System
SAO	Smithsonian Astrophysical Observatory
SAREX	Shuttle Amateur Radio Experiment
SARSAT	Satellite Aided Search and Rescue Program
SBIR	Small Business Innovation Research
SBUV	Solar Background Ultra-Violet
SCS	Soil Conservation Service
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SEALAR	Sea Launch and Recovery
Seasat	Experimental oceanic surveillance satellite launched June 27, 1978; it demonstrated that much useful information about the ocean could be obtained through satellite surveillance
SeaWIFS	Sea-Viewing Wide Field Sensor
SEDS	Small Expendable Deployer System
SEI	Space Exploration Initiative
SEM	Space Environment Monitor
SETI	Search for Extraterrestrial Intelligence
S-GCOS	Space-based Global Change Observation System
SHARE	Space Station Heat Pipe Advanced Radiator Element
SIMMOD	Simulation Model
SMEX	Small Explorer
SIRTF	Space Infrared Telescope Facility
SLAR	Side-Looking Airborne Radar
SLC	Space Launch Complex
SLS	Space Life Sciences Laboratory
SLV	Space Launch Vehicle

SNOTEL	SNOWpack TELemetry
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOHO	Solar and Heliospheric Observatory
solar flare	A sudden, intense brightening of a portion of the Sun's surface, often near a sunspot group; these flares, enormous eruptions of energy that leap millions of miles from the Sun's surface, pose a potential radiation hazard to humans in space
solar maximum	The period in the roughly 11-year cycle of solar activity when the maximum number of sunspots is present
solar wind	A stream of particles accelerated by the heat of the solar corona (outer region of the Sun) to velocities great enough to permit them to escape from the Sun's gravitational field
SOLSTICE	Solar/Stellar Irradiance Comparison Experiment
SPAS	Shuttle Pallet Satellite
SPEAR	Space Power Experiment Aboard Rocket
SPOT	Satellite Pour l'Observation de la Terre (satellite for the observation of the Earth)
SPPD	Signal Processing Packaging Design
SRAM	Static Random Access Memory
SRM&QA	Safety, Reliability, Maintainability, and Quality Assurance
SSAAC	Space Science and Applications Advisory Committee
SSBUV	Shuttle Solar Backscatter Ultraviolet
SSCE	Solid Surface Combustion Experiment
SSF	Space Station Freedom
SSME	Space Shuttle Main Engine
SSMI	Special Sensor Microwave/Imager
SSMT	Special Sensor Microwave/Temperature
SST	Sea Surface Temperature
START	Strategic Arms Reduction Treaty
STDN	Spaceflight Tracking and Data Network
STGT	Second TDRSS Ground Terminal
STME	Space Transportation Main Engine
STOL	Short Takeoff and Landing
STORM-FEST	Storm-Fronts Experiment Systems Test
STOVL	Short Take-off and Vertical Landing (Aircraft)
STS	Space Transportation System
STV	Space Transfer Vehicle
sunspot	A vortex of gas on the surface of the Sun associated with stray local magnetic activity
SUPER	Name for a survivable solar-power subsystem demonstrator
super high frequency	Any frequency between 3,000 and 30,000 megacycles per second
supernova	An exceptionally bright nova, a variable star whose brightness changes suddenly, which exhibits a luninosity ranging from 10 million to 100 million times that of our Sun
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
SWAS	Submillimeter Wave Astronomy Satellite
TASS	Terminal Area Surveillance System
TCAS	Traffic Alert and Collision Avoidance System
TDRS	Tracking and Data Relay Satellite
TDRSS	TDRS System
TDWR	Terminal Doppler Weather Radar
TFE	Thermionic Fuel Element
thermionics	A field of electronics that uses electrical current passing through a gaseous medium (vacuum tube) instead of a solid state (semi-conductor), permitting use in high-temperature and radiation environments in which other electronic devices fail
TIMED	Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics
TIROS	Television and Infrared Operational Satellite

TM	Thematic Mapper
TNA	Thermal Neutron Analysis
TOMS	Total Ozone Mapping Spectrometer
TONS	TDRSS Onboard Navigation System
TOPEX	Ocean Topography Experiment
TOPS	Toward Other Planetary Systems
TOS	Transfer Orbit Stage
TOVS	TIROS Operational Vertical Sounder
TPCE	Tank Pressure Control Experiment
TR	Thrust-reversing
TRACON	Terminal Radar Approach Control
tribology	The study of the interaction of sliding surfaces with respect to friction, wear, and lubrication
TRMM	Tropical Rainfall Measuring Mission
TSS	Tethered Satellite System
TV	Thrust-vectoring
TVCS	Thrust Vector Control System
UARS	Upper Atmosphere Research Satellite
UFO	UHF Follow-on
UHF	Ultra High Frequency, any frequency between 300 and 3,000 megacycles per second
UIT	Ultraviolet Imaging Telescope
UMS	Urine Monitoring System
UNEP	United Nations Environment Program
USAF	U.S. Air Force
USCINCSPACE	Commander-in-Chief, U.S. Space Command
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USML	U.S. Microgravity Laboratory
USMP	U.S. Microgravity Payload
UV	Ultraviolet
UVCS	Ultraviolet Coronal Spectrometer
VAS	Visible-and-Infrared-Spin-Scan-Radiometer Atmospheric Sounder
VCS	Voice Command System
very high frequency	Any radio frequency between 30 and 300 megacycles per second
VFC	Vortex Flow Control
VLBI	Very Long Baseline Interferometry
VLSI	Very Large Scale Integration
VoA	Voice of America
WARC	World Administrative Radio Conference
WEFAX	Weather Facsimile
WGD	(CEOS) Working Group on Data
white dwarf	Any of a class of faint stars, characterized not only by low luminosity but by masses and radii comparable to that of our Sun
WINDII	Wind Imaging Interferometer
WMO	World Meteorological Organization
WSGT	White Sands Ground Terminal
WSMC	Western Space and Missile Center
WSP	Windshear Processor
WUPPE	Wisconsin Ultraviolet Photopolarimeter Experiment
x-rays	Radiations of very short wavelengths, beyond the ultra-violet in the spectrum
XTE	X-ray Timing Explorer

APPENDIXES

APPENDIX A-1

U.S. Government Spacecraft Record

(Includes spacecraft from cooperating countries launched by U.S. launch vehicles.)

Calendar Year	Earth Orbit[a]		Earth Escape[a]	
	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	2
1962	55	12	4	1
1963	62	11	0	0
1964	69	8	4	0
1965	93	7	4	1
1966	94	12	7	1[b]
1967	78	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1
1972	33	2	8	0
1973	23	2	3	0
1974	27	2	1	0
1975	30	4	4	0
1976	33	0	1	0
1977	27	2	2	0
1978	34	2	7	0
1979	18	0	0	0
1980	16	4	0	0
1981	20	1	0	0
1982	21	0	0	0
1983	31	0	0	0
1984	35	3	0	0
1985	37	1	0	0
1986	11	4	0	0
1987	9	1	0	0
1988	16	1	0	0
1989	24	0	2	0
1990	40	0	1	0
1991	32[c]	0	0	0
1992 *(through September 30)*	17[c]	0	1	0
TOTAL	1,250	144	83	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.

[c] This excludes commercial satellites.

APPENDIX A-2

World Record Of Space Launches Successful in Attaining Earth Orbit or Beyond

(Enumerates launches rather than spacecraft; some launches orbited multiple spacecraft.)

Calendar Year	United States	USSR/ CIS	France/ Canada[a]	Italy/ Indonesia[a]	Japan	People's Republic of China	Australia	United Kingdom	European Space Agency	India	Israel
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[b]	1	1					
1971	30	83	1	2[b]	2	1		1			
1972	30	74		1	1						
1973	23	86									
1974	22	81		2[b]	1						
1975	27	89	3	1	2	3					
1976	26	99			1	2					
1977	24	98			2						
1978	32	88			3	1					
1979	16	87			2				1		
1980	13	89			2					1	
1981	18	98			3	1			2	1	
1982	18	101			1	1					
1983	22	98			3	1			2	1	
1984	22	97			3	3			4		
1985	17	98			2	1			3		
1986	6	91			2	2			2		
1987	8	95			3	2			2		
1988	12	90			2	4			7		
1989	17	74			2				7		1
1990	27	75			3	5			5		1
1991	13[c]	62	1		2	1			9	1	
TOTAL	936	2,318	1		43	29	1	1	44	4	2
1992 *(through Sept. 30)*	18[c]	34		1	2	1	1		3	2	
TOTAL	954	2,352	1	1	45	30	2	1	47	6	2

[a]Since 1979 all launches for ESA member countries have been joint and are listed under ESA. These headings reflect launches for France and Italy between 1957 and 1978 and for Canada and Indonesia beginning in 1991. Totals at the bottom reflect only Canada and Indonesia.

[b]Includes foreign launches of U.S. spacecraft.

[c]This excludes commercial expendable launches.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Nov. 8 USA-72 76A Titan IV	*Objective:* To place satellite into successful orbit from which DoD objectives can be met. *Spacecraft:* Not announced.	Not announced	In orbit.
Nov. 8 USA-74 76C Titan IV	*Objective:* To place satellite into successful orbit from which DoD objectives can be met. *Spacecraft:* Not announced.	Not announced	In orbit.
Nov. 8 USA-76 76D Titan IV	*Objective:* To place satellite into successful orbit from which DoD objectives can be met. *Spacecraft:* Not announced.	Not announced	In orbit.
Nov. 8 USA-77 76E Titan IV	*Objective:* To place satellite into successful orbit from which DoD objectives can be met. *Spacecraft:* Not announced.	Not announced	In orbit.
Nov. 24 Space Shuttle Atlantis (STS-44) 80A	*Objective:* To deploy a Defense Support Program (DSP) satellite and to work with a variety of secondary payloads: Interim Operational Contamination Monitor in the Cargo Bay; Terra Scout, Military Man in Space (M88-1), Air Force Maui Optical System, Cosmic Radiation Effects and Activation Monitor, Shuttle Activation Monitor, and 3 others as Middeck Payloads. *Spacecraft:* Shuttle orbiter carrying the experiments listed above.	368.0 361.0 91.6 28.4	Forty-fourth flight of the Space Transportation System. Piloted by Fred Gregory and Tom Henricks. Mission specialists Jim Voss, Story Musgrave and Mario Runco, Jr. Payload specialist Tom Hennen. Launched from KSC, 6:44 p.m. EST. Landed at Edwards AFB, CA, 5:34 p.m. EST, Dec. 2. Mission duration: 6 days, 22 hours, 51 minutes.
Nov. 25 Defense Support Program (DSP-I) USA-75 80B	*Objective:* To launch an enhanced Defense Support Program (DSP) satellite, the third in the "DSP-I" block of satellites. *Spacecraft:* A survivable and reliable system that detects and reports on real-time missile launches, space launches and nuclear detonations.	Not announced	Satellite successfully launched from Atlantis by an Inertial Upper Stage with two solid rocket motors at 7:16 a.m. EST. The DSP weighs approximately 2,360 kg. and is about 10 meters long. It measures about 6.7 meters across its deployed solar array surface area and employs infrared detectors to sense heat from missile plumes.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Nov. 28 Defense Meteorological Satellite (F-11) USA-73 82A Atlas E	*Objective:* To launch the first of the improved Block 5D-2 satellites in the Defense Meteorological Satellite Program. The sensor complement on this satellite includes the first water vapor profiler placed in orbit. This sensor provides information on the vertical humidity profile and water vapor content on a global basis.	855.0 835.0 101.8 98.9	One in a series of Defense Meteorological Satellites. Launched from SLC-3W of Vandenberg AFB, CA.
Jan. 22 Space Shuttle Discovery (STS-42) 2A	*Objective:* To conduct a world-wide research effort in the behavior of materials and life in weightlessness. *Spacecraft:* Shuttle orbiter carrying the International Microgravity Laboratory-1 (IML-1) in the cargo bay. IML-1 included 42 experiments in life and materials sciences. In addition, STS-42 included Get Away Special payloads from 6 countries, including China for the first time, and the 5th Shuttle flight of the Investigations into Polymer Membrane Processing (IPMP), among others.	305.0 293.0 90.5 56.9	Forty-fifth flight of the Space Transportation System. Piloted by Col. Ronald J. Grabe (USAF) and Stephen S. Oswald. Mission specialists Dr. Norman E. Thagard, MD; Lt. Col. David C. Hilmers (USMC); and William F. Readdy. Payload specialists Dr. Roberta L. Bondar, PhD and MD of the CSA and Ulf Merbold of the ESA. Launched 9:55 a.m. EST from Kennedy Space Center. Landed 11:07 a.m. EST, Jan. 30 at Edwards AFB.
Feb. 10 DSCS III USA-78 6A Atlas II	*Objective:* To launch a new Defense Satellite Communications System (DSCS) III satellite. *Spacecraft:* 110" long, 76" wide, 77" deep. Six SHF channels.	Not announced	This launch marked the start of a replenishment program for the DSCS constellation of satellites.
Feb. 23 GPS USA-79 9A Delta II	*Objective:* To add to the existing constellation of Global Positioning System satellites in orbit. *Spacecraft:* A Block IIA satellite operating in inclined, semi-synchronous orbit.	20,323.0 20,039.0 717.9 54.6	Twelfth in a series of operational GPS satellites. System expected to be composed of 24 satellites in 6 orbital planes. In orbit.
Mar. 14 Galaxy 5 13A Atlas I	*Objective:* To launch a commercial communications satellite. *Spacecraft:* A communications satellite carrying 24 C-band transponders.	35,789.0 35,787.0 1,436.1	Launched from Cape Canaveral, AFS FL. In orbit.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Mar. 24 Space Shuttle Atlantis (STS-45) 15A	*Objective:* To study the Sun, the upper reaches of the Earth's atmosphere, and astronomical objectives. *Spacecraft:* Shuttle orbiter carrying the Atmospheric Laboratory for Applications and Science-1 (ATLAS-1) containing 12 instruments from 7 countries that will conduct 13 experiments to study the chemistry of the atmosphere, solar radiation, space plasma physics, and ultraviolet astronomy. STS-45 also carried other experiments including IPMP.	304.0 292.0 90.4 57.0	Forty-sixth flight of the Space Transportation System. Piloted by Col. Charles F. Bolden (USMC) and Lt. Col. Brian Duffy (USAF). Mission specialists Kathryn D. Sullivan, Capt. David C. Leestma (USN), and Michael Foale. Payload specialists Dirk D. Frimout (ESA) and Byron K. Lichtenberg. Launched at 6:13 a.m. EST from KSC. Landed 6:23 a.m. EST at Rwy 33 of the KSC Shuttle Landing Facility on Apr. 2.
Apr. 10 GPS USA-80 19A Delta II	*Objective:* To add to the existing constellation of Global Positioning System satellites in orbit. *Spacecraft:* A Block IIA satellite operating in inclined, semi-synchronous orbit.	20,381.0 19,981.0 718.0 55.2	Thirteenth in a series of operational GPS satellites. System expected to be composed of 24 satellites in 6 orbital planes. In orbit.
Apr. 25 USA-81 23A Titan IV	*Objective:* To place satellite into successful orbit from which DoD objectives can be met. *Spacecraft:* Not announced.	Not announced	Launched from Vandenberg AFB, CA. In orbit.
May 7 Space Shuttle Endeavour (STS-49) 26A	*Objective:* To rendezvous with, repair, and reboost a crippled INTELSAT VI communications satellite. *Spacecraft:* Shuttle orbiter with INTELSAT perigee kick motor and support equipment, including a capture bar assembly, plus equipment to demonstrate and verify Space Station Freedom maintenance and assembly tasks as well as a protein crystal growth experiment. First flight of newest orbiter, Endeavour.	375.0 363.0 91.9 28.3	Forty-seventh flight of the Space Transportation System. Piloted by Capt. Daniel C. Brandenstein (USN) and Lt. Col. Kevin P. Chilton (USAF). Mission specialists Richard J. Hieb, Cmdr. Bruce E. Melnick (USCG), Cmdr. Pierre J. Thuot (USN), Kathryn C. Thornton, and Thomas D. Akers. Launched 7:40 p.m. EDT from KSC. Landed 4:57 p.m. EDT May 16 at Edwards AFB.
May 14 Palapa B-4 27A Delta	*Objective:* To launch an Indonesian communications satellite.	35,799.0 35,777.0 1,436.2 0.0	Launched by a Delta rocket. Specifics unavailable.
Jun. 7 Extreme Ultra-violet Explorer (EUVE) 31A Delta II	*Objective:* To launch a satellite that will make both spectroscopic and wide-band observations over the entire extreme ultraviolet spectrum. *Spacecraft:* Rectangular shaped body with dual solar arrays. Four telescopes, each 40 centimeters across: three scanners and one deep survey/ spectrometer telescope.	532.0 517.0 95.1 28.4	Launched aboard a Delta-II rocket from Cape Canaveral. Returning data. In orbit.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jun. 10 Intelsat-K 32A Atlas IIA	*Objective:* To launch the highest powered Intelsat satellite to date. *Spacecraft:* A communications satellite equipped with sixteen 54 megahertz transponders.	35,791.0 35,782.0 1,436.1 0.0	Launched on an Atlas IIA from Cape Canaveral AFS. In orbit. Entered into service Sep. 1, 1992.
Jun. 25 Space Shuttle Columbia (STS-50) 34A	*Objective:* To perform around-the-clock investigations of the effects of weightlessness on plants, humans, and materials. *Spacecraft:* Shuttle orbiter carrying U.S. Microgravity Laboratory-1, including 31 experiments ranging from manufacturing crystals for possible semiconductor use to the behavior of weightless fluids. Also includes the Investigations into Polymer Membrane Processing experiment and the Space Shuttle Amateur Radio Experiment-II.	309.0 297.0 90.6 28.5	Forty-eighth flight of the Space transportation system. Piloted by Richard N. Richards and Kenneth D. Bowersox. Mission specialists Bonnie Dunbar, Ellen Baker, and Col. (USAF) Carl Meade. Payload specialists Lawrence J. DeLucas and Eugene H. Trinh. Launched from Kennedy Space Ctr. at 12:12 p.m., EDT. Landed at Kennedy Space Center July 9 at 7:43 a.m. EDT after a record-breaking 13 days, 19 hours, and 31 minutes flight.
Jul. 2 DSCS III USA-82 37A Atlas II	*Objective:* To launch a new Defense Satellite Communications System (DSCS) III satellite. *Spacecraft:* 110" long, 76" wide, 77" deep. Six SHF channels.	Not announced	In orbit.
Jul. 3 Solar, Anomalous and Magnetospheric Particle Explorer (SAMPEX) 38A Scout	*Objective:* To launch the first spacecraft in a new series of Small Explorers designed to investigate anomalous cosmic rays, galactic cosmic rays in the vicinity of Earth, solar energetic particles, and other phenomena of space physics. *Spacecraft:* The first in NASA's new Small Explorer series, the rectangular spacecraft weighing 348 pounds was 4.5 feet tall and 2.8 feet wide without its two solar arrays deployed; they extended its width to 6.9 feet. Carries four cosmic monitoring instruments.	684.0 511.0 96.7 81.7	Launched into near-polar orbit by a Scout rocket at 10:19 a.m. EDT from Vandenberg AFB. In orbit. Built by the Goddard Space Flight Center, SAMPEX carries scientific instruments from the University of Maryland, California Institute of Technology, the Aerospace Corporation, and the Max Planck Institute for extraterrestrial Physics in Germany.
Jul. 7 GPS USA-83 39A Delta II	*Objective:* To add to the existing constellation of Global Positioning System satellites in orbit. *Spacecraft:* A Block IIA satellite operating in inclined, semi-synchronous orbit.	20,403.0 19,960.0 718.0 55.0	Fourteenth in a series of operational GPS satellites. System expected to be composed of 24 satellites in 6 orbital planes. In orbit.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jul. 24 Geotail 44A Delta II	*Objective:* To investigate the geomagnetic tail region of the magnetosphere. *Spacecraft:* A spin-stabilized, cylindrical satellite approximately 2.2 meters in diameter with a height of 1.6 meters and a weight of about 1,009 kg. 2 mechanically despun antennas. Designed by the Institute of Space and Astronautical Science (ISAS) of Japan, with 2 ISAS, 2 NASA, and 3 joint ISAS/NASA instruments. An element in the International Solar Terrestrial Physics (ISTP) Program.	341,116.0 184.0 2,354.5 28.7	Launched by a Delta II–the first such launch under NASA's Medium ELV launch service contract with McDonnell Douglas Corporation–at 10:26 a.m. EDT from Cape Canaveral. The initial orbit is far distant from the Earth and will last about 2 1/4 years, after which the satellite will be maneuvered closer in to measure the midmagnetosphere instead of the geomagnetic tail region of the magnetosphere examined earlier. In orbit.
Jul. 31 Space Shuttle Atlantis (STS-46) 49A	*Objective:* To evaluate the capability for safely deploying, controlling, and retrieving a tethered satellite and to demonstrate the capability of the system to serve as a facility for research in geophysical and space physics. *Spacecraft:* Shuttle orbiter carrying Tethered Satellite System-1, a joint project of the United States and Italy weighing 1,139 lbs. The crew was able to deploy the TSS satellite to only 256 meters instead of the goal of 20 kilometers. Other payloads included ESA's Eureca-1, an IMAX camera for filming parts of the mission, and 4 experiments.	306.0 299.0 90.6 28.5	Forty-ninth flight of the Space transportation system. Piloted by Col. Loren J. Shriver (USAF) and Maj. Andrew M. Allen (USMC). Mission specialists Claude Nicollier (ESA), Marsha S. Ivins, Jeffrey A. Hoffman, and Franklin R. Chang-Diaz. Payload specialist Franco Malerba (Italian Space Agency). Atlantis launched at 9:56 a.m. EDT from Kennedy Space Center. Landed at KSC's Shuttle Landing Facility at 9:12 a.m. EDT Aug. 8.
Aug. 2 Eureka-1 49B	*Objective:* To perform research in the fields of material and life sciences plus radio-biology in a controlled microgravity environment at an operational orbit of 515 km. and return to a lower orbit for retrieval by another orbiter. *Spacecraft:* European Retrievable Carrier (Eureka) designed and developed by ESA. A rectangular satellite with twin solar arrays, equipped with an altitude and orbit control system to keep disturbance or microgravity experiments at a minimum. Launch mass: 4,491 kg.	509.0 504.0 94.8 28.5	Successfully deployed by Space Shuttle Atlantis and subsequently boosted to its desired orbit using its own propulsion on Aug. 6. To remain in orbit for 6 to 9 months before retrieval.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Aug. 10 TOPEX/POSEIDON 52A Ariane 42P	*Objective:* To increase our understanding of global ocean dynamics by making precise and accurate observations of sea level, thus yielding global ocean topography. *Spacecraft:* Basically rectangular satellite with a single solar array and five instruments, 3 provided by NASA (a Dual-Frequency Radar Altimeter, the TOPEX Microwave Radiometer, and a Global Positioning Demonstration Receiver) and 2 by the French Centre d'Etudes Spatiales (a Dual-Doppler Tracking System Receiver and a Single-Frequency Solid-State Radar Altimeter). Joint U.S.-French spacecraft, part of NASA's Mission to Planet Earth; weight, 2,520 kg.; length, 5.5 m.; span, 11.5 m; height, 6.6 m.	1,341.0 1,330.0 112.4 66.0	Successfully launched from Kourou, French Guiana on an Ariane 42P booster at 8:08 p.m. local time. On Sep. 21 the satellite completed the last of 6 maneuvers that placed it in the required orbit.
Aug. 31 Satcom C4 57A Delta II	*Objective:* To launch a commercial communications satellite. Satellite: A communications satellite to support cable TV programming.	35,814.0 35,761.0 1,436.2 0.2	Successfully launched from Cape Canaveral. In orbit.
Sep. 9 GPS USA-84 58A Delta II	*Objective:* To add to the existing constellation of Global Positioning System satellites in orbit. *Spacecraft:* A Block IIA satellite operating in inclined, semi-synchronous orbit.	20,630.0 19,979.0 723.0 54.8	Fifteenth in a series of operational GPS satellites. System expected to be composed of 24 satellites in 6 orbital planes. In orbit.
Sep. 10 Satcom C3 60B Ariane 44LP	*Objective:* To launch a commercial communications satellite. *Satellite:* A communications satellite to provide domestic service.	35,799.0 35,780.0 1,436.3 0.1	Successfully launched from Kourou, French Guiana by an Ariane 44LP. In orbit.
Sep. 12 Space Shuttle Endeavour (STS-47) 61A	*Objective:* To perform successfully the materials and life science investigations of Spacelab J, a joint laboratory sponsored by NASA and the National Space Development Agency (NASDA) of Japan. *Spacecraft:* Shuttle orbiter carrying 24 materials science and 19 life science investigations involving government, industry, and university sponsors in Japan and the U.S. STS-47 secondary objectives included 9 Get-away Special (GAS) experiments, the Israel Space Agency Investigation about Hornets (ISAIAH), Shuttle Amateur Radio Experiment (SAREX), and the Solid Surface Combustion Experiment (SSCE). Payload weight: about 28,158 pounds.	301.0 297.0 90.5 56.9	Fiftieth flight of Space Transportation System. Piloted by Robert L. Gibson and Curtis L. Brown, Jr. Mission specialists Mark C. Lee, Jerome Apt, N. Jan Davis, and Dr. Mae C. Jemison, the first African-American woman to fly in space. Payload specialist Mamoru Mohri, the first Japanese to fly aboard a NASA spacecraft. Lee and Davis were the first married couple in space together. Endeavour launched at 10:23 a.m. EDT at Kennedy Space Ctr. Landed there at 8:53 a.m. EDT on Sep. 20.

Successful U.S. Launches

October 1, 1991–September 30, 1992

Launch Date (GMT). Spacecraft Name, COSPAR Designation, Launce Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Sep. 25 Mars Observer 63A Titan III	*Objective:* To study the geology, geophysics, and climate of Mars. *Spacecraft:* Rectangular satellite with solar power, 7 complementary instruments (Gamma Ray Spectrometer, Mars Observer Science Camera, Thermal Emission Spectrometer, Pressure Modulator Infrared Radiometer, Mars Observer Laser Altimeter, Radio Science, and Magnetometer and Electron Reflectometer) and a Mars Balloon Relay to relay scientific telemetry from equipment deployed by the Russian Mars 94 mission.	On way to Mars orbit	Successfully launched from Complex 40 at Cape Canaveral AFS at 1:05 p.m. EDT with its Transfer Orbit Stage to a parking orbit from which the TOS ignited setting the satellite on its 11-month journey to Mars orbit, expected to begin in August 1993.

U.S.-Launched Applications Satellites, 1986-1992

Date	Name	Launch Vehicle	Remarks
		COMMUNICATIONS	
Jan. 12, 1986	RCA Satcom K-1	Space Shuttle	Launched for RCA American Communications, Inc.
Dec. 5, 1986	Fltsatcom 7	Atlas-Centaur	Launched for DoD.
Mar. 20, 1987	Palapa B-2P	Delta 182	Indonesia domestic communications.
Sept. 25, 1989	Fltsatcom F-8	Atlas/Centaur	Sixth, and last in series of geosynchronous satellites, for U.S. Navy.
Jan. 1, 1990	Skynet 4A	Titan III	Launched for British Ministry of Defense.
Jan. 1, 1990	JCSAT 2	Titan III	Second of dual Titan III launch, for Japanese Communications Satellite Co.
Jan. 9, 1990	Syncom IV-5	Space Shuttle	Leasat 5, fourth in series of satellites, for U.S. Navy.
Mar. 14, 1990	Intelsat 6 F-3	Titan III	Launched for INTELSAT.
Apr. 13, 1990	Palapa-B2R	Delta	Launched for Indonesia.
Jun. 23, 1990	Intelsat 6 F-4	Titan III	Launched for INTELSAT.
Aug. 18, 1990	BSB-2R	Delta	Launched for British Satellite Broadcasting.
Feb. 10, 1992	DSCS III	Atlas II	Launched by the Air Force for the DoD.
Mar. 14, 1992	Galaxy 5	Atlas I	Commercial communications satellite.
May 14, 1992	Palapa-B4	Delta	Launched for Indonesia.
Jun. 10, 1992	INTELSAT K	Atlas IIA	Launched for INTELSAT.
Jul. 2, 1992	DSCS III	Atlas II	Launched by the Air Force for the DoD.
Aug. 31, 1992	Satcom C4	Delta II	Commercial communications satellite.
		WEATHER OBSERVATION[a]	
Sep. 17, 1986	NOAA-10	Atlas E	Launched for NOAA.
Feb. 26, 1987	GOES 7	Delta 179	Launched for NOAA, operational as GOES-East.
Jun. 20, 1987	DMSP F-8	Atlas E	Third in block 5D-2 series, DoD meteorological satellite.
Feb. 2, 1988	DMSP F-9	Atlas E	DoD Meteorological satellite.
Sep. 24, 1988	NOAA-11	Atlas E	Launched for NOAA, to repair NOAA-9.
Dec. 1, 1990	DMSP F-10	Atlas E	DoD meteorological satellite.
May 14, 1991	NOAA-12	Atlas E	Launched for NOAA.
Nov. 28, 1992	DMSP F-11	Atlas E	DoD meteorological satellite.
		EARTH OBSERVATION	
None launched since 1984.			
		GEODESY	
None launched since 1985.			
		NAVIGATION[a]	
Apr. 25, 1988	SOOS-3	Scout	Dual satellites, part of Navy navigation system.
Jun. 16, 1988	NOVA-2	Scout	Third of improved Transit System satellities, for DoD.
Aug. 25, 1988	SOOS-4	Scout	Dual Satellites, part of Navy navigation system.
Feb. 14, 1989	GPS-1 (Block IIR)	Delta II	Global Positioning System Satellite.
June 10, 1989	GPS-2 (Block IIR)	Delta II	Global Positioning System Satellite.
Aug. 18, 1989	GPS-3 (Block IIR)	Delta II	Global Positioning System Satellite.
Oct. 21, 1989	GPS-4 (Block IIR)	Delta II	Global Positioning System Satellite.
Dec. 11, 1989	GPS-5 (Block IIR)	Delta II	Global Positioning System Satellite.
Jan. 24, 1990	GPS-6 (Block IIR)	Delta II	Global Positioning System Satellite.
Mar. 26, 1990	GPS-7 (Block IIR)	Delta II	Global Positioning System Satellite.
Aug. 2, 1990	GPS-8 (Block IIR)	Delta II	Global Positioning System Satellite.
Oct. 1, 1990	GPS-9 (Block IIR)	Delta II	Global Positioning System Satellite.
Nov. 16, 1990	GPS-10 (Block IIR)	Delta II	Global Positioning System Satellite.
Jul. 4, 1991	GPS-11 (Block IIR)	Delta II	Global Positioning System Satellite.
Feb. 23, 1992	GPS-12 (Block IIR)	Delta II	Global Positioning System Satellite.
Apr. 10, 1992	GPS-13 (Block IIR)	Delta II	Global Positioning System Satellite.
Jul. 7, 1992	GPS-14 (Block IIR)	Delta II	Global Positioning System Satellite.
Sep. 9, 1992	GPS-15 (Block IIR)	Delta II	Global Positioning System Satellite.

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

U.S.-Launched Scientific Satellites, 1986-1992

Date	Name	Launch Vehicle	Remarks
Nov. 14, 1986	Polar Bear	Scout	Experiments to study radio interference caused by Aurora Borealis, for DoD.
Mar. 25, 1988	San Marco D/L	Scout	International satellite to study Earth's lower atmosphere.
Nov. 18, 1989	COBE	Delta	Measurement of cosmic background.
Feb. 14, 1990	LACE	Delta II	Low-powered atmospheric compensation experiment, for DoD.
Feb. 14, 1990	RME	Delta II	Second payload, relay mirror experiment satellite, for DoD.
Apr. 5, 1990	PEGSAT	Pegasus	Chemical release experiment satellite for NASA and DoD.
Apr. 25, 1990	Hubble Space Telescope	Space Shuttle	Long-term astronomical observations.
June 1, 1990	ROSAT	Delta II	Measurement of x-ray and extreme ultraviolet sources.
Jul. 25, 1990	CRRES	Atlas/Centaur	Chemical release experiment.
Apr. 7, 1991	Compton Gamma Ray Observatory	Space Shuttle	Measurement of celestial gamma-rays.
Sep. 15, 1991	Upper Atmosphere Research Satellite	Space Shuttle	Measurement of Earth's atmosphere and ozone layer.
Jun. 7, 1992	Extreme Ultra-violet Explorer	Delta II	Spectroscopic and wide-band observations over the entire extreme ultraviolet spectrum.
Jul. 3, 1992	Solar, Anomalous and Magnetospheric Particle Explorer	Scout	Investigation of cosmic rays and other phenomena of space physics.
Jul. 24, 1992	Geotail	Delta II	Investigation of geomagnetic tail region of the magnetosphere.
Aug. 2, 1992	Eureka-1	Space Shuttle	Research in the fields of material and life sciences.

U.S.-Launched Space Probes, 1975-1992

Date	Name	Launch Vehicle	Remarks
Aug. 20, 1975	Viking 1	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Chryse, Sept. 6, 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of atmosphere.
Sept 9, 1975	Viking 2	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Utopia, July 20, 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of the atmosphere.
Jan. 15, 1976	Helios 2	Titan IIIE-Centaur	Flew in highly elliptical orbit to within 41 million km. of Sun, measuring solar wind, corona, electrons, and cosmic rays. Payload had some West German and U.S. experiments as Helios 1 plus cosmic-ray burst detector.
Aug. 20, 1977	Voyager 2	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Swung around Jupiter in July 1979, arrived Saturn in 1981, going on to Uranus by 1986, Neptune by 1989.
Sept. 5, 1977	Voyager 1	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Passing Voyager 2 on the way, swung around Jupiter in Mar. 1979, arrived at Saturn in Nov. 1980, headed for outer solar system.
May 20, 1978	Pioneer Venus 1	Atlas-Centaur	Venus orbiter, achieved Venus orbit Dec. 4, returning imagery and data.
Aug. 8, 1978	Pioneer Venus 2	Atlas-Centaur	Carried 1 large, 3 small probes plus spacecraft bus; all descended through Venus atmosphere Dec. 9, returned data.
May 4, 1989	Magellan	Space Shuttle	Venus orbiter, achieved Venus orbit Aug. 10, 1990, returning radar image of surface.
Oct. 18, 1989	Galileo	Space Shuttle	Planetary exploration spacecraft, composed of probe to enter Jupiter's atmosphere and orbiter to return scientific data.
Oct. 6, 1990	Ulysses	Space Shuttle	Solar exploration spacecraft, to explore interstellar space and the Sun.
Sep. 25, 1992	Mars Observer	Titan III	Planetary exploration spacecraft to study the geology, geophysics, and climate of Mars.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Vostok 1	Apr. 12, 1961	Yuriy A. Gagarin	0:1:48	First human flight.
Mercury-Redstone 3	May 5, 1961	Alan B. Shepard, Jr.	0:0:15	First U.S. flight; suborbital.
Mercury-Redstone 4	July 21, 1961	Virgil I. Grissom	0:0:16	Suborbital; capsule sank after landing; astronaut safe.
Vostok 2	Aug. 6, 1961	German S. Titov	1:1:18	First flight exceeding 24 hrs.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	0:4:55	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	0:4:56	Landed 400 km. beyond target.
Vostok 3	Aug. 11, 1962	Andriyan G. Nikolayev	3:22:25	First dual mission (with Vostok 4).
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	2:22:59	Came within 6 km. of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	0:9:13	Landed 8 km. from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	1:10:20	First U.S. flight exceeding 24 hrs.
Vostok 5	June 14, 1963	Valeriy F. Bykovskiy	4:23:6	Second dual mission (withVostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	2:22:50	First woman in space; within 5 km. of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Boris G. Yegorov	1:0:17	First 3-person crew.
Voskhod 2	Mar. 18, 1965	Pavel I. Belyayev Aleksey A. Leonov	1:2:2	First extravehicular activity (Leonov, 10 min.).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	0:4:53	First U.S. 2-person flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, II	4:1:56	21-min. extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	7:22:55	Longest-duration human flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	13:18:35	Longest human flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	1:1:51	Rendezvous within 30 cm. of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	0:10:41	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	3:0:21	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	2:22:47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini II	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	2:23:17	First initial-orbit docking; first tethered flight; highest Earth-orbit altitude (1,372 km.).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	3:22:35	Longest extravehicular activity to date (Aldrin, 5 hrs.)
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	1:2:37	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	10:20:9	First U.S. 3-person mission.
Soyuz 3	Oct. 26, 1968	Georgiy T. Beregovoy	3:22:51	Maneuvered near uncrewed Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	6:3:1	First human orbit(s) of Moon; first human departure from Earth's sphere of influence; highest speed attained in human flight to date.
Soyuz 4	Jan. 14, 1969	Vladimir A. Shatalov	2:23:23	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris V. Volynov Aleksey A. Yeliseyev Yevgeniy V. Khrunov	3:0:56	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	10:1:1	Successfully simulated in Earth-orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	8:0:3	Successfully demonstrated complete system including lunar module to 14,300 m. from the lunar surface.
Apollo II	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	8:3:9	First human landing on lunar surface and safe return to Earth. First return of rock and soil samples to Earth, and human deployment of experiments on lunar surface.
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy N. Kubasovf	4:22:42	Soyuz 6, 7, and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and Earth and celestial observation.
Soyuz 7	Oct. 12, 1969	A. V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4:22:41	
Soyuz 8	Oct. 13, 1969	Vladimir A. Shatalov Aleksey S. Yeliseyev	4:22:50	
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	10:4:36	Second human lunar landing Explored surface of Moon and retrieved parts of Surveyor 3 spacecraft, which landed in Ocean of Storms on Apr. 19, 1967.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	5:22:55	Mission aborted; explosion in ervice module. Ship circled, Moon, with crew using LM as "lifeboat" until just before reentry.
Soyuz 9	June 1, 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17:16:59	Longest human spaceflight to date.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	9:0:2	Third human lunar landing. Mission demonstrated pinpoint landing capability and continued human exploration.
Soyuz 10	Apr. 22, 1971	Vladimir A. Shatalov Aleksey S. Yeliseyev Nikolay N. Rukavishnikov	1:23:46	Docked with Salyut 1, but crew did not board space station launched Apr. 19. Crew recovered Apr. 24, 1971.
Soyuz II	June 6, 1971	Georgiy T. Dobrovolskiy Vladislav N. Volkov Viktor I. Patsayev	23:18:22	Docked with Salyut 1 and Soyuz II crew occupied space station for 22 days. Crew perished in final phase of Soyuz II capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James B. Irwin	12:7:12	Fourth human lunar landing and first Apollo "J" series mission, which carried Lunar Roving Vehicle. Worden's inflight EVA of 38 min. 12 sec was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly II	11:1:51	Fifth human lunar landing, with Lunar Roving Vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	12:13:52	Sixth and final Apollo human lunar landing, again with roving vehicle.
Skylab 2	May 25, 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	28:0:50	Docked with Skylab 1 (launched uncrewed May 14) for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	59:11:9	Docked with Skylab 1 for more than 59 days.
Soyuz 12	Sept. 27, 1973	Vasiliy G. Lazarev Oleg G. Makarov	1:23:16	Checkout of improved Soyuz.
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	84:1:16	Docked with Skylab 1 in long-duration mission; last of Skylab program.
Soyuz 13	Dec. 18, 1973	Petr I. Klimuk Valentin V. Lebedev	7:20:55	Astrophysical, biological, and Earth resources experiments.
Soyuz 14	July 3, 1974	Pavel R. Popovich Yuriy P. Artyukhin	15:17:30	Docked with Salyut 3 and Soyuz 14 crew occupied space station.
Soyuz 15	Aug. 26, 1974	Gennadiy V. Sarafanov Lev. S. Demin	2:0:12	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatoliy V. Filipchenko Nikolay N. Rukavishnikov	5:22:24	Test of ASTP configuration.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz 17	Jan. 10, 1975	Aleksay A. Gubarev Georgiy M. Grechko	29:13:20	Docked with Salyut 4 and occupied station.
Anomaly	Apr. 5, 1975	Vasiliy G. Lazarev Oleg G. Makarov	0:0:20	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr I. Klimuk Vitaliy I. Sevastyanov	62:23:20	Docked with Salyut 4 and occupied station.
Soyuz 19	July 15, 1975	Aleksey A. Leonov Valeriy N. Kubasov	5:22:31	Target for Apollo in docking and joint experiments of ASTP mission.
Apollo	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	9:1:28	Docked with Soyuz 19 in joint (ASTP) experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris V. Volynov Vitaliy M. Zholobov	48:1:32	Docked with Salyut 5 and occupied station.
Soyuz 22	Sept. 15, 1976	Valeriy F. Bykovskiy Vladimir V. Aksenov	7:21:54	Earth resources study with multispectral camera system.
Soyuz 23	Oct. 14, 1976	Vyacheslav D. Zudov Valeriy I. Rozhdestvenskiy	2:0:6	Failed to dock with Salyut 5.
Soyuz 24	Feb. 7, 1977	Viktor V. Gorbatko Yuriy N. Glazkov	17:17:23	Docked with Salyut 5 and occupied station.
Soyuz 25	Oct. 9, 1977	Vladimir V. Kovalenok Valeriy V. Ryumin	2:0:46	Failed to achieve hard dock with Salyut 6 station.
Soyuz 26	Dec. 10, 1977	Yuriy V. Romanenko Georgiy M. Grechko	37:10:6	Docked with Salyut 6. Crew returned in Soyuz 27; crew duration 96 days 10 hrs.
Soyuz 27	Jan. 10, 1978	Vladimir A. Dzhanibekov Oleg G. Makarov	64:22:53	Docked with Salyut 6. Crew returned in Soyuz 26; crew duration 5 days, 22 hrs., 59 min.
Soyuz 28	Mar. 2, 1978	Aleksey A. Gubarev Vladimir Remek	7:22:17	Docked with Salyut 6. Remek was first Czech cosmonaut to orbit.
Soyuz 29	June 15, 1978	Vladimir V. Kovalenok Aleksandr S. Ivanchenkov	9:15:23	Docked with Salyut 6. Crew returned in Soyuz 31; crew duration 139 days, 14 hrs, 48 min.
Soyuz 30	June 27, 1978	Petr I. Klimuk Miroslaw Hermaszewski	7:22:4	Docked with Salyut 6. Hermaszewski was first Polish cosmonaut to orbit.
Soyuz 31	Aug. 26, 1978	Valeriy F. Bykovskiy Sigmund Jaehn	67:20:14	Docked with Salyut 6. Crew returned in Soyuz 29; crew duration 7 days, 20 hrs, 49 min. Jaehn was first German Democratic Republic cosmonaut to orbit.
Soyuz 32	Feb. 25, 1979	Vladimir A. Lyakhov Valeriy V. Ryumin Nikolay N. Rukavishnikov	108:4:24	Docked with Salyut 6. Crew returned in Soyuz 34; crew duration 175 days, 36 min.
Soyuz 33	Apr. 10, 1979	Georgi I. Ivanov	1:23:1	Failed to achieve docking with Salyut 6 station. Ivanov was first Bulgarian cosmonaut to orbit.
Soyuz 34	June 6, 1979	(unmanned at launch)	7:18:17	Docked with Salyut 6, later served as ferry for Soyuz 32 crew while Soyuz 32 returned without a crew.
Soyuz 35	Apr. 9, 1980	Leonid I. Popov Valeriy V. Ryumin	55:1:29	Docked with Salyut 6. Crew returned in Soyuz 37. Crew duration 184 days, 20 hrs, 12 min.
Soyuz 36	May 26, 1980	Valeriy N. Kubasov Bertalan Farkas	65:20:54	Docked with Salyut 6. Crew returned in Soyuz 35. Crew duration 7 days, 20 hrs, 46 min. Farkas was first Hungarian to orbit.
Soyuz T-2	June 5, 1980	Yuriy V. Malyshev Vladimir V. Aksenov	3:22:21	Docked with Salyut 6. First crewed flight of new-generation ferry.
Soyuz 37	July 23, 1980	Viktor V. Gorbatko Pham Tuan	79:15:17	Docked with Salyut 6. Crew returned in Soyuz 36. Crew duration 7 days, 20 hrs, 42 min. Pham was first Vietnamese to orbit.
Soyuz 38	Sept. 18, 1980	Yuriy V. Romanenko Arnaldo Tamayo Mendez	7:20:43	Docked with Salyut 6. Tamayo was first Cuban to orbit.
Soyuz T-3	Nov. 27, 1980	Leonid D. Kizim Oleg G. Makarov Gennadiy M. Strekalov	12:19:8	Docked with Salyut 6. First 3-person flight in Soviet program since 1971.
Soyuz T-4	Mar. 12, 1981	Vladimir V. Kovalenok Viktor P. Savinykh	74:18:38	Docked with Salyut 6.
Soyuz 39	Mar. 22, 1981	Vladimir A. Dzhanibekov Jugderdemidiyn Gurragcha	7:20:43	Docked with Salyut 6. Gurragcha first Mongolian cosmonaut to orbit.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle Columbia (STS 1)	Apr .12, 1981	John W. Young Robert L. Crippen	2:6:21	First flight of Space Shuttle, tested spacecraft in orbit. First landing of airplane-like craft from orbit for reuse.
Soyuz 40	May 14, 1981	Leonid I. Popov Dumitru Prunariu	7:20:41	Docked with Salyut 6. Prunariu first Romanian cosmonaut to orbit.
Space Shuttle Columbia (STS 2)	Nov. 12, 1981	Joe H. Engle Richard H. Truly	2:6:13	Second flight of Space Shuttle, first scientific payload (OSTA 1). Tested remote manipulator arm. Returned for reuse.
Space Shuttle Columbia (STS 3)	Mar. 22, 1982	Jack R. Lousma C. Gordon Fullerton	8:4:49	Third flight of Space Shuttle, second scientific payload (0SS 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	May 13, 1982	Anatoliy Berezovoy Valentin Lebedev	211:9:5	Docked with Salyut 7. Crew duration of 211 days. Crew returned in Soyuz T-7.
Soyuz T-6	June 24, 1982	Vladimir Dzhanibekov Aleksandr Ivanchenkov Jean-Loup Chrétien	7:21:51	Docked with Salyut 7. Chrétien first French cosmonaut to orbit.
Space Shuttle Columbia (STS 4)	June 27, 1982	Thomas K. Mattingly II Henry W. Hartsfield, Jr.	7:1:9	Fourth flight of Space Shuttle, first DoD payload, additional scientific payloads. Returned July 4. Completed testing program. Returned for reuse.
Soyuz T-7	Aug. 19, 1982	Leonid Popov Aleksandr Serebrov Svetlana Savitskaya	7:21:52	Docked with Salyut 7. Savitskaya second Soviet woman to orbit. Crew returned in Soyuz T-5.
Space Shuttle Columbia (STS 5)	Nov. 11, 1982	Vance D. Brand Robert F. Overmyer Joseph P. Allen William B. Lenoir	5:2:14	Fifth flight of Space Shuttle, first operational flight; launched 2 commercial satellites (SBS 3 and Anik C- 3); first flight with 4 crew members. EVA test canceled when space suits malfunctioned.
Space Shuttle Challenger (STS 6)	Apr. 4, 1983	Paul J. Weitz Karol J. Bobko Donald H. Peterson Story Musgrave	5:0:24	Sixth flight of Space Shuttle, launched TDRS 1.
Soyuz T-8	Apr. 20, 1983	Vladimir Titov Gennady Strekalov Aleksandr Serebrov	2:0:18	Failed to achieve docking with Salyut 7 station.
Space Shuttle Challenger . (STS 7)	June 18, 1983	Robert L. Crippen Frederick H. Hauck John M. Fabian Sally K. Ride Norman T. Thagard	6:2:24	Seventh flight of Space Shuttle, launched 2 commercial satellites (Anik C-2 and Palapa B-l), also launched and retrieved SPAS 01; first flight with 5 crewmembers, including first woman U.S. astronaut.
Soyuz T-9	June 28, 1983	ladimir Lyakhov Aleksandr Aleksandrov	149:9:46	Docked with Salyut 7 station.
Space Shuttle Challenger (STS 8)	Aug. 30, 1983	Richard H. Truly Daniel C. Brandenstein Dale A. Gardner Guion S. Bluford, Jr. William E. Thornton	6:1:9	Eighth flight of Space Shuttle, launched one commercial satellite (Insat l-B), first flight of U.S. black astronaut.
Space Shuttle Columbia (STS 9)	Nov. 28, 1983	John W. Young Brewster W. Shaw Owen K. Garriott Robert A. R. Parker Byron K. Lichtenberg Ulf Merbold	10:7:47	Ninth flight of Space Shuttle, first flight of Spacelab 1, first flight of 6 crew members, one of whom was West German, first non-U.S. astronaut to fly in U.S. space program (Merbold).
Space Shuttle Challenger (STS-41B)	Feb. 3, 1984	Vance D. Brand Robert L. Gibson Bruce McCandless Ronald E. McNair Roben L. Stewart	7:23:16	Tenth flight of Space Shuttle, two communication satellites failed to achieve orbit. First use of Manned Maneuvering Unit (MMU) in space.
Soyuz T-10	Feb. 8, 1984	Leonid Kizim Vladimir Solovev Oleg Atkov	62:22:43	Docked with Salyut 7 station. Crew set space duration record of 237 days. Crew returned in Soyuz T-ll.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz T-11	Apr. 3, 1984	Yuriy Malyshev Gennadiy Strekalov Rakesh Sharma	181:21:48	Docked with Salyut 7 station. Sharma first Indian in space. Crew returned in Soyuz T-10.
Space Shuttle Challenger (STS-41C)	Apr. 6, 1984	Robert L. Crippen Frances R. Scobee Terry J. Hart George D. Nelson James D. van Hoften	6:23:41	Eleventh flight of Space Shuttle, deployment of LDEF-1, for later retrieval, Solar Maximum Satellite retrieved, repaired, and redeployed.
Soyuz T-12	July 17, 1984	Vladimir Dzhanibekov Svetlana Savistskaya Igor Volk	11:19:14	Docked with Salyut 7 station. First female extravehicular activity.
Space Shuttle Discovery (STS-41D)	Aug. 30, 1984	Henry W. Hartsfield Michael L. Coats Richard M. Mullane Steven A. Hawley Judith A. Resnick Charles D. Walker	6:0:56	Twelfth flight of Space Shuttle. First flight of U.S. non-astronaut.
Space Shuttle Challenger (STS-41G)	Oct. 5, 1984	Robert L. Crippen Jon A. McBride Kathryn D. Sullivan Sally K. Ride David Leestma Paul D. Scully-Power Marc Garneau	8:5:24	Thirteenth flight of Space Shuttle, first of 7 crew members, including first flight of two U.S. women and one Canadian (Garneau).
Space Shuttle Discovery (STS-51A)	Nov. 8, 1984	Frederick H. Hauck David M. Walker Joseph P. Allen Anna L. Fisher Dale A. Gardner	7:23:45	Fourteenth flight of Space Shuttle, first retrieval and return of two disabled communications satellites (Westar 6, Palapa B2) to Earth.
Space Shuttle Discovery (STS-51C)	Jan. 24, 1985	Thomas K. Mattingly Loren J. Shriver Ellison S. Onizuka James F. Buchli Gary E. Payton	3:1:33	Fifteenth STS flight. Dedicated DoD mission.
Space Shuttle Discovery (STS-51D)	Apr. 12, 1985	Karol J. Bobko Donald E. Williams M. Rhea Seddon S. David Griggs Jeffrey A. Hoffman Charles D. Walker E. J. Garn	6:23:55	Sixteenth STS flight. Two communications satellites First U.S. Senator in space (Garn).
Space Shuttle Challenger (STS-51B)	Apr. 29, 1985	Robert F. Overmyer Frederick D. Gregory Don L. Lind Norman E. Thagard William E. Thornton Lodewijk van den Berg Taylor Wang	7:0:9	Seventeenth STS flight. Spacelab-3 in cargo bay of shuttle.
Soyuz T-13	June 5, 1985	Vladimir Dzhanibekov Viktor Savinykh	112:3:12	Repair of Salyut-7. Dzhanibekov returned to Earth with Grechko on Soyuz T-13 spacecraft, Sept. 26, 1985.
Space Shuttle Discovery (STS-51G)	June 17, 1985	Daniel C. Brandenstein John O. Creighton Shannon W. Lucid John M. Fabian Steven R. Nagel Patrick Baudry Sultan bin Salman bin Abdul-Aziz Al-Saud	7:1:39	Eighteenth STS flight. Three communications satellites. One reusable payload, Spartan-1. First U.S. flight with French and Saudi Arabian crewmen.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle Challenger (STS-51F)	July 29, 1985	Charles G. Fullerton Roy D. Bridges Karl C. Henize Anthony W. England F. Story Musgrave Loren W. Acton John-David F. Bartoe	7:22:45	Nineteenth STS flight. Spacelab-2 in cargo bay.
Space Shuttle Discovery (STS-51I)	Aug. 27, 1985	Joe H. Engle Richard O. Covey James D. van Hoften William F. Fisher John M. Lounge	7:2:18	Twentieth STS flight. Launched three communications satellites. Repaired Syncom IV-3.
Soyuz T-14	Sept. 17, 1985	Vladimir Vasyutin Georgiy Grechko Aleksandr Volkov	64:21:52	Docked with Salyut 7 station. Viktor Savinykh, Aleksandr Volkov and Vladimir Vasyutin returned to Earth Nov. 21, 1985, when Vasyutin became ill.
Space Shuttle Atlantis (STS-51J)	Oct. 3, 1985	Karol J. Bobko Ronald J. Grabe Robert A. Stewart David C. Hilmers William A. Pailes	4:1:45	Twenty-first STS flight. Dedicated DOD mission.
Space Shuttle Challenger (STS-61A)	Oct. 30, 1985	Henry W. Hartsfield Steven R. Nagel Bonnie J. Dunbar James F. Buchli Guion S. Bluford Ernst Messerschmid Reinhard Furrer (FRG) Wubbo J. Ockels (ESA)	7:0:45	Twenty-second STS flight. Dedicated German Spacelab D-1 in shuttle cargo bay.
Space Shuttle Atlantis (STS-61B)	Nov. 27, 1985	Brewster H. Shaw Bryan D. O'Connor Mary L. Cleve Sherwood C. Spring Jerry L. Ross Rudolfo Neri Vela Charles D. Walker	6:22:54	Twenty-third STS flight. Launched three communications satellites. First flight of Mexican astronaut (Neri Vela).
Space Shuttle Columbia (STS-61C)	Jan. 12, 1986	Robert L. Gibson Charles F. Bolden Jr. Franklin Chang-Diaz Steve A. Hawley George D. Nelson Roger Cenker Bill Nelson	6:2:4	Twenty-fourth STS flight. Launched one communications satellite. First member of U.S. House of Representatives in space (Bill Nelson).
Soyuz T-15	Mar. 13, 1986	Leonid Kizim Vladimir Solovyov	125:1:1	Docked with MIR space station on May 5/6 transferred to Salyut 7 complex. On June 25/26 transferred from Salyut 7 back to MIR.
Soyuz TM-2	Feb. 5, 1987	Yuriy Romanenko Aleksandr Laveykin	174:3:26	Docked with MIR space station. Romanenko established long distance stay in space record of 326 days.
Soyuz TM-3	July 22, 1987	Aleksandr Viktorenko Aleksandr Aleksandrov Mohammed Faris	160:7:16	Docked with MIR space station. Aleksandr Aleksandrov remained in MIR 160 days, returned with Yuriy Romanenko. Viktorenko and Faris returned in Soyuz TM-2, July 30 with Aleksandr Laveykin who experienced medical problems. Mohammed Faris first Syrian in space.
Soyuz TM-4	Dec. 21, 1987	Vladimir Titov Musa Manarov Anatoliy Levchenko	180:5	Docked with MIR space station. Crew of Yuriy Romanenko, Aleksandr Aleksandrov, and Anatoliy Levchenko returned Dec. 29 in Soyuz TM-3.
Soyuz TM-5	Jun. 7, 1988	Viktor Savinykh Anatoly Solovyev Aleksandur Aleksandrov	9:20:13	Docked with MIR space station, Aleksandrov first Bulgarian in space. Crew returned Jun. 17 in Soyuz TM-4.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz TM-6	Aug. 29, 1988	Vladimir Lyakhov Valeriy Polyakov Abdul Mohmand	8:19:27	Docked with MIR space station, Mohmand first Afghanistani in space. Crew returned Sept. 7, in Soyuz TM-5.
STS-26	Sept. 29, 1988	Frederick H. Hauck Richard O. Covey John M. Lounge David C. Hilmers George D. Nelson	4:1	Twenty-sixth STS flight. Launched TDRS 3.
Soyuz TM-7	Nov. 26, 1988	Aleksandr Volkov Sergey Krikalev Jean-Loup Chrétien	151:11	Docked with MIR space station. Soyuz TM-6 returned with Chrétien, Vladimir Titov, and Musa Manarov. Titov and Manarov completed 366-day mission Dec. 21. Crew of Krikalev, Volkov, and Valeriy Polyakov returned Apr. 27, 1989 in Soyuz TM-7.
STS-27	Dec. 2, 1988	Robert "Hoot" Gibson Guy S. Gardner Richard M. Mullane Jerry L. Ross William M. Shepherd	4:9:6	Twenty-seventh STS flight. Dedicated DoD mission.
STS-29	Mar. 13, 1989	Michael L. Coats John E. Blaha James P. Bagian James F. Buchli Robert C. Springer	4:23:39	Twenty-eighth STS flight. Launched TDRS-4.
STS-30	May 4, 1989	David M. Walker Ronald J. Grabe Nomman E. Thagard Mary L. Cleave Mark C. Lee	4:0:57	Twenty-ninth STS flight. Venus orbiter Magellan launched.
STS-28	Aug. 8, 1989	Brewster H. Shaw Richard N. Richards James C. Adamson David C. Leestma Mark N. Brown	5:1	Thirtieth STS flight. Dedicated DoD mission.
Soyuz TM-8	Sept. 5, 1989	Aleksandr Viktorenko Aleksandr Serebrov	166:6	Docked with MIR space station. Crew of Viktorenko and Serebrov returned in Soyuz TM-8, Feb. 9, 1990.
STS-34	Oct. 18, 1989	Donald E. Williams Michael J. McCulley Shannon W. Lucid Franklin R. Chang-Diaz Ellen S. Baker	4:23:39	Thirty-first STS flight. Launched Jupiter probe and orbiter Galileo.
STS-33	Nov. 23, 1989	Frederick D. Gregory John E. Blaha Kathryn C. Thornton F. Story Musgrave Manley L. "Sonny" Carter	5:0:7	Thirty-second STS flight. Dedicated DoD mission.
STS-32	Jan. 9, 1990	Daniel C. Brandenstein James D. Wetherbee Bonnie J. Dunbar Marsha S. Ivins G. David Low	10:21	Thirty-third STS flight. Launched Syncom IV-5 and retrieved Long-Duration Exposure Facility (LDEF).
Soyuz TM-9	Feb. 11, 1990	Anatoliy Solovyov Aleksandr Balandin	178:22:19	Docked with MIR space station. Crew returned Aug. 9, 1990, in Soyuz TM-9.
STS-36	Feb. 28, 1990	John O. Creighton John H. Casper David C. Hilmers Richard H. Mullane Pierre J. Thout	4:10:19	Thirty-fourth STS flight. Dedicated DoD mission.

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
STS-31	Apr. 24, 1990	Loren J. Shriver Charles F. Bolden, Jr. Steven A. Hawley Bruce McCandless II Kathryn D. Sullivan	5:1:16	Thirty-fifth STS flight. Launched Hubble Space Telescope (HST).
Soyuz TM-10	Aug. 1, 1990	Gennadiy Manakov Gennadiy Strekalov	130:20:36	Docked with MIR space station. Crew returned Dec. 10, 1990, with Toyohiro Akiyama, Japanese astronaut.
STS-41	Oct. 6, 1990	Richard N. Richards Robert D. Cabana Bruce E. Melnick William M. Shepherd Thomas D. Akers	4:2:10	Thirty-sixth STS flight. Ulysses spacecraft to investigate interstellar space and the Sun.
STS-38	Nov. 15, 1990	Richard O. Covey Frank L. Culbertson, Jr. Charles "Sam" Gemar Robert C. Springer Carl J. Meade	4:21:55	Thirty-seventh STS flight. Dedicated DoD mission.
STS-35	Dec. 2, 1990	Vance D. Brand Guy S. Gardner Jeffrey A. Hoffman John M. "Mike" Lounge Robert A. R. Parker	8:23:5	Thirty-eighth STS flight. ASTRO-1 in cargo bay.
Soyuz TM-11	Dec. 2, 1990	Viktor Afanasyev Musa Manarov	175:01:52	Docked with MIR space station. Toyohiro Akiyama returned Dec. 10, 1990, with previous MIR crew of Gennadiy Manakov and Gennadiy Strekalov.
STS-37	Apr. 5, 1991	Steven R. Nagel Kenneth D. Cameron Linda Godwin Jerry L. Ross Jay Apt	6:0:32	Thirty-ninth STS flight. Launched Gamma Ray Observatory to measure celestial gamma-rays.
STS-39	Apr. 28, 1991	Michael L. Coats Blaine Hammond, Jr. Gregory L. Harbaugh Donald R. McMonagle Guion S. Bluford Lacy Veach Richard J. Hieb	8:7:22	Fortieth STS flight. Dedicated DoD mission.
Soyuz TM-12	May 18, 1991	Anatoly Artsebarskiy Sergei Krikalev Helen Sharman (UK)	144:15:22	Docked with MIR space station. Helen Sharman first from United Kingdom to fly in space. Crew of Viktor Afanasyev, Musa Manarov, and Helen Sharman returned May 20, 1991. Artsebarskiy and Krikalev remained on board MIR, with Artsebarskiy returning Oct. 10, 1991, and Krikalev doing so Mar. 25, 1992.
STS-40	Jun. 5, 1991	Bryan D. O'Conner Sidney M. Gutierrez James P. Bagian Tamara E. Jernigan M. Rhea Seddon Francis A. "Drew" Gaffney Millie Hughes-Fulford	9:2:15	Forty-first STS flight. Carried Spacelab Life Sciences (SLS-1) in cargo bay.
STS-43	Aug. 2, 1991	John E. Blaha Michael A. Baker Shannon W. Lucid G. David Low James C. Adamson	8:21:21	Forty-second STS flight. Launched fourth Tracking and Data Relay Satellite (TDRS-5).
STS-48	Sept. 12, 1991	John Creighton Kenneth Reightler, Jr. Charles D. Gemar James F. Buchli Mark N. Brown	5:8:28	Forty-third STS flight. Launched Upper Atmosphere Research Satellite (UARS).

U.S. and Soviet/CIS Human Spaceflights, 1961-1992

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz TM-13	Oct. 2, 1991	Aleksandr Volkov Toktar Aubakirov (Kazakh Republic) Franz Viehboeck (Austria)	90:16:00	Docked with MIR space station. Crew returned Oct. 10, 1991, with Anatoly Artsebarsky.
STS-44	Nov. 24, 1991	Frederick D. Gregory Tom Henricks Jim Voss Story Musgrave Mario Runco, Jr. Tom Hennen	6:22:51	Forty-fourth STS flight. Launched Defense Support Program (DSP) satellite.
STS-42	Jan. 22, 1992	Ronald J. Grabe Stephen S. Oswald Norman E. Thagard David C. Hilmers William F. Readdy Roberta L. Bondar Ulf Merbold (ESA)	8:1:12	Forty-fifth STS flight. Carried International Microgravity Laboratory-1 in cargo bay.
Soyuz TM-14	Mar. 17, 1992	Alexandr Viktorenko Alexandr Kaleri Klaus-Dietrich Flade (Germany)	145:15:11	First manned CIS space mission. Docked with Mir space station Mar. 19. The TM-13 capsule with Flade, Aleksandr Volkov, and Sergei Krikalev returned to Earth Mar. 25. Krikalev had been in space 313 days. Viktorenko and Kaleri remained in the TM-14 spacecraft.
STS-45	Mar . 24, 1992	Charles F. Bolden Brian Duffy Kathryn D. Sullivan David C. Leestma Michael Foale Dirk D. Frimout Byron K. Lichtenberg	9:0:10	Forty-sixth STS flight. Carried Atmospheric Laboratory for Applications and Science (ATLAS-1).
STS-49	May 7, 1992	Daniel C. Brandenstein Kevin P. Chilton Richard J. Hieb Bruce E. Melnick Pierre J. Thuot Kathryn C. Thornton Thomas D. Akers	8:16:17	Forty-seventh STS flight. Reboosted a crippled INTELSAT VI communications satellite.
STS-50	Jun. 25, 1992	Richard N. Richards Kenneth D. Bowersox Bonnie Dunbar Ellen Baker Carl Meade	13:19:30	Forty-eighth STS flight. Carried U.S. Microgravity Laboratory-1.
Soyuz TM-15	Jul. 27, 1992	Anatoly Solovyov Sergei Avdeyev Michel Tognini (France)		Docked with Mir Space Station Jul. 29. Tognini returned to Earth in TM-14 capsule with Alexandr Viktorenko and Alexandr Kaleri. Solovyov and Avdeyev remained on Mir. Mission still in progress.
STS-46	Jul. 31, 1992	Loren J. Shriver Andrew M. Allen Claude Nicollier (ESA) Marsha S. Ivins Jeffrey A. Hoffman Franklin R. Chang-Diaz Franco Malerba (Italy)	7:23:16	Forty-nineth STS flight. Deployed Tethered Satellite System-1 and Eureka-1.
STS-47	Sep. 12, 1992	Robert L. Gibson Curtis L. Brown, Jr. Mark C. Lee Jerome Apt N. Jan Davis Mae C. Jemison Mamoru Mohri (Japan)	7:22:30	Fiftieth STS flight. Carried Spacelab J. Jemison first African American woman to fly in space. Mohri first Japanese to fly on NASA spacecraft. Lee and Davis first married couple in space together.

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[b]	Max. Dia x Height (m)	Max. Payload (kg)[c]			First Launch[e]
					185-Km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[d]	
Scout G-1				1.14x22.90	255[f]	54 210[d]	155	1979 [60]
	1. Algol IIIA	Solid	414.8 (SL)	1.14x9.40				
	2. Castor IIA	Solid	267.2	0.79x6.31				
	3. Antares IIIA	Solid	80.8	0.76x3.51				
	4. Altair III	Solid	25.8	0.51x1.48				
Pegasus				6.71x15.04 (wing span)	380 280[d]	—	210	1990
	1. Orion 50S	Solid	580.5	1.28x8.88				
	2. Orion 50	Solid	138.6	1.28x2.66				
	3. Orion 38	Solid	35.8	0.97x1.34				
Delta II (6920, 6925)				2.44x38.20	3983 2943[d] (6920 vers)	1447 (6925 vers)	2413	1989 [60] (6920 vers)
	1. RS-270/B	LOX/RP-1	921.0 (SL)	2.44x38.20				
	Castor IVA (9)	Solid	432.0 (ea)	1.01x11.16				
	2. AJ10-118K	N_2O_4/A-50	42.9	2.44x5.97				
	3. Star 48B (6925)	Solid	67.2	1.25x2.04				
Delta II (7920, 7925)				2.44x29.70	5039 3819[d]	1819 (7925 vers)	3175	1990 [60] (7920 vers)
	1. RS-270/Cs	LOX/RP-1	894.4 (SL)	2.90x26.09				
	Hercules GEM (9)	Solid	440.0 (ea)	1.01x12.95				
	2. AJ10-118K	N_2O_4/A-50	42.9	2.44x5.97				
	3. Star 48B (7925)	Solid	67.2	1.25x2.04				
Atlas E				3.05x28.1	820[d] 1860[dg]	—	910[g]	1968 [58] (Atlas B)
	1. Atlas: MA-3	LOX/RP-1	1739.5 (SL)	3.05x21.3				
Atlas I				3.05x45.6	5900	2375	—	1990 [66] (Atlas Centaur)
	1. Atlas: MA-5	LOX/RP-1	1954.0 (SL)	3.05x22.16				
	2. Centaur I: RL10A-3-3A (2)	LOX/LH_2	73.4 (ea)	3.05x9.14				
Atlas II				3.05x49.3	6580	2610	4300	1991 [66] (Atlas Centaur)
	1. Atlas: MA-5A	LOX/RP-1	2110.0 (SL)	3.05x24.9				
	2. Centaur II: RL10A-3-3A (2)	LOX/LH_2	73.4 (ea)	3.05x10.05				
Atlas IIA				3.05x49.3	7280	2745	4750	1992 [66] (Atlas Centaur)
	1. Atlas: MA-5A	LOX/RP-1	2110.0 (SL)	3.05x24.9				
	2. Centaur II: RL10A-4 (2)	LOX/LH_2	92.5 (ea)	3.05x10.05				
Titan II				3.05x42.9	1905[d]	—	—	1988 [64]
	1. LR-87-AJ-5 (2)	N_2O_4/A-50	1045.0 (ea)	3.05x21.5				
	2. LR-91-AJ-5	N_2O_4/A-50	440.0	3.05x12.2				

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[b]	Max. Dia x Height (m)	Max. Payload (kg)[c] 185-Km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[d]	First Launch[e]
Titan III				3.05x47.3	14515	4990[h]	—	1989 [66]
	0. Titan III SRM (2) (5-1/2 segments)	Solid	6210.0 (ea)	3.05x27.6				(Titan IIIB)
	1. LR87-AJ-11 (2)	N_2O_4/A-50	1214.5 (ea)	3.05x24.0				
	2. LR91-AJ-11	N_2O_4/A-50	462.8	3.05x10.0				
Titan IV				3.05x47.3	17700	6350[i]	—	1989 [66]
	0. Titan IV SRM (2) (7 segments)	Solid	8000.0 (ea)	3.05x34.1	14110[d]			(Titan IIIB)
	1. LR87-AJ-11 (2)	N_2O_4/A-50	1214.5 (ea)	3.05x26.4				
	2. LR91-AJ-11	N_2O_4/A-50	462.8	3.05x10.0				
Space Shuttle[j]				23.79x56.14 (wing span)	24900[k]	5900[l]	—	1981
	1. SRB: Shuttle SRB (2)	Solid	13616.0(ea)	3.70x45.46				
	2. Orbiter/ET:SSME (3)	LOX/LH_2	1668.7(ea)	8.41x47.00 (external tank) 23.79x37.24 (orbiter)				
	3. Orbiter/OMS: OMS engines (2)	N_2O_4/MMH	118.8(ea)	23.79x37.24 (orbiter)				

Notes

[a] Propellant abbreviations used are as follows:
A-50 = Aerozine 50 (50% Monomethyl Hydrazine, 50% Unsymmetrical Dimethyl Hydrazine)
LH_2 = Liquid Hydrogen; LOX=Liquid Oxygen
MMH = Monomethyl Hydrazine
N_2O_4 = Nitrogen Tetroxide
RP-1 = Rocket Propellant 1 (kerosene)
Solid = Solid Propellant (any type)

[b] Thrust at vacuum except where indicated at sea level (SL).

[c] Launch inclination of 28.5° except where indicated.

[d] Polar launch from Vandenberg AFB, CA.

[e] Latest version [initial version].

[f] 37.7° launch from Wallops Flight Facility, VA.

[g] With TE-M-364-4 upper stage.

[h] With Transfer Orbit Stage (TOS).

[i] With appropriate upper stage.

[j] Space Shuttle Solid Rocket Boosters (SRBs) fire in parallel with the Space Shuttle Main Engines (SSMEs), which are mounted on the aft end of the Shuttle Orbiter Vehicle (OV) and burn fuel and oxidizer from the External Tank (ET). SRBs stage first, with SSMEs continuing to fire. The ET stages next, just before the orbiter attains orbit. The Orbiter Maneuvering Subsystem (OMS) is then used to maneuver or change the orbit of the OV.

[k] 280 x 420 km. orbit.

[l] With Inertial Upper Stage (IUS) or Transfer Orbit Stage (TOS).

NOTE: **Data should not be used for detailed NASA mission planning without concurrence of the Director of Space Transportation System Support Programs.**

SOURCE OF DATA: David H. Burks, Senior Engineer, Science Applications International Corporation, Washington, DC.

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY—BUDGET AUTHORITY
(in millions of dollars)

Fiscal Year	NASA Total	NASA Space[a]	Defense	Other	Energy	Com-merce	Inter-ior	Agri-culture	NSF	DOT	EPA	Total Space
1959	331	261	490	...	34	...	...	...	...	...	...	785
1960	524	462	561	...	43	...	...	...	0.1	...	...	1,066
1961	964	926	814	...	68	...	...	...	0.6	...	...	1,808
1962	1,825	1,797	1,298	...	148	51	...	...	1.3	...	...	3,295
1963	3,673	3,626	1,550	...	214	43	...	...	1.5	...	...	5,435
1964	5,100	5,016	1,599	...	210	3	...	...	3.0	...	...	6,831
1965	5,250	5,138	1,574	...	229	12	...	...	3.2	...	...	6,956
1966	5,175	5,065	1,689	...	187	27	...	...	3.2	...	...	6,970
1967	4,966	4,830	1,664	...	184	29	...	...	2.8	...	...	6,710
1968	4,587	4,430	1,922	...	145	28	0.2	0.5	3.2	...	...	6,529
1969	3,991	3,822	2,013	...	118	20	0.2	0.7	1.9	...	...	5,976
1970	3,746	3,547	1,678	...	103	8	1.1	0.8	2.4	...	...	5,341
1971	3,311	3,101	1,512	127	95	27	1.9	1	2	...	...	4,741
1972	3,307	3,071	1,407	97	55	31	5.8	2	3	...	...	4,575
1973	3,406	3,093	1,623	109	54	40	10.3	2	3	...	...	4,825
1974	3,037	2,759	1,766	116	42	60	9.0	3	2	...	...	4,640
1975	3,229	2,915	1,892	107	30	64	8.3	2	2	...	...	4,914
1976	3,550	3,225	1,983	111	23	72	10.4	4	2	...	...	5,320
Transit Qtr	932	849	460	31	5	22	2.6	1	1	...	...	1,341
1977	3,818	3,440	2,412	131	22	91	10	6	2	...	...	5,983
1978	4,060	3,623	2,738	157	34	103	10	8	2	...	...	6,518
1979	4,596	4,030	3,036	178	59	98	10	8	2	...	...	7,244
1980	5,240	4,680	3,848	160	40	93	12	14	2	...	...	8,689
1981	5,518	4,992	4,828	158	41	87	12	16	2	...	...	9,978
1982	6,044[b]	5,528	6,679	234	61	145	12	15	2	...	...	12,441
1983	6,875[c]	6,328	9,019	242	39	178	5	20	...[d]	...	...	15,589
1984	7,248	6,648	10,195	293	34	236	3	19	...	...	...	17,136
1985	7,573	6,925	12,768	474	34	423	2	15	...	...	...	20,167
1986	7,766	7,165	14,126	368	35	309	2	23	...	...	...	21,659
1987	10,507	9,809[e]	16,287	352	48	278	8	19	...	1	...	26,448
1988	9,026	8,302	17,679	626	241	352	14	18	...	1	...	26,607
1989	10,969	10,098	17,906	440	97	301	17	21	...	3	1	28,443
1990	13,073	12,142	15,616	383	79	243	31	25	...	4	1	28,140
1991	14,004	13,036	14,181	426	108	251	36	26	...	4	1	27,643
1992	14,316	13,199	*	485	97	327	27	29	...	4	2	*

[a]Excludes amounts for air transportation (subfunction 402).
[b]Includes $33.5 million for unobligated funds that lapsed.
[c]Includes $37.6 million for reappropriation of prior year funds.
[d]NSF funding of balloon research transferred to NASA.
[e]Includes $2.1 billion for replacement of shuttle orbiter Challenger.

*1991 Defense funding for space was not available before publication. Contact NASA History Division at (202) 358-0385 for updated information.

SOURCE: Office of Management and Budget.

APPENDIX E-2

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority			Budget Outlays		
	1990 actual	1991 actual	1992 estimated	1990 actual	1991 actual	1992 estimated
NASA	12,142	13,036	13,199	12,292	13,351	12,838
Defense	15,616	14,181	*	12,962	14,432	*
Energy	79	108	97	79	108	97
Commerce	243	251	327	279	266	298
Interior	31	36	27	31	36	25
Agriculture	25	26	29	25	26	29
Transportation	4	4	4	3	4	4
EPA	1	1	2	1	1	2
TOTAL	28,140	27,643	*	25,671	28,224	*

*1991 Defense funding for space was not available before publication. Contact NASA History Division at (202) 358-0385 for updated information.

SOURCE: Office of Management and Budget.

APPENDIX E-3

Federal Aeronautics Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority			Budget Outlays		
	1990 actual	1991 actual	1992 estimated	1990 actual	1991 actual	1992 estimated
NASA[a]	932	968	1,117	889	1,017	1,122
Defense[b]	7,867	6,148	*	7,649	6,792	*
Transportation[c]	1,891	2,300	2,627	1,471	1,691	2,099
TOTAL	10,690	9,416	*	10,009	9,500	*

[a]Research, 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.

*1991 Defense funding for space was not available before publication. Contact NASA History Division at (202) 358-0385 for updated information.

SOURCE: Office of Management and Budget.

The White House

Washington

FEBRUARY 5, 1992

NATIONAL SPACE POLICY DIRECTIVE 5

MEMORANDUM FOR THE VICE PRESIDENT
THE SECRETARY OF STATE
THE SECRETARY OF THE TREASURY
THE SECRETARY OF DEFENSE
THE SECRETARY OF THE INTERIOR
THE SECRETARY OF AGRICULTURE
THE SECRETARY OF COMMERCE
THE SECRETARY OF TRANSPORTATION
THE SECRETARY OF ENERGY
CHIEF OF STAFF TO THE PRESIDENT
DIRECTOR OF THE OFFICE OF MANAGEMENT AND BUDGET
THE ASSISTANT TO THE PRESIDENT FOR NATIONAL SECURITY AFFAIRS
THE ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY POLICY
THE DIRECTOR OF CENTRAL INTELLIGENCE
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SUBJECT: Landsat Remote Sensing Strategy

I. Policy Goals

A remote sensing capability such as is currently being provided by Landsat satellites 4 and 5 benefits the civil and national security interests of the United States and makes contributions to the private sector which are in the public interest. For these reasons, the United States government will seek to maintain continuity of Landsat-type data. The U.S. government will:

(a) Provide data which are sufficiently consistent in terms of acquisition geometry, coverage characteristics, and spectral characteristics with previous Landsat data to allow comparisons for change detection and characterization;

(b) Make Landsat data available to meet the needs of national security, global change research, and other federal users; and,

(c) Promote and not preclude private sector commercial opportunities in landsat-type remote sensing.

II. Landsat Strategy

a. The Landsat strategy is composed of the following elements:

(1) Ensuring that Landsat satellites 4 and 5 continue to provide data as long as they are technically capable of doing so, or until Landsat 6 becomes operational.

(2) Acquiring a Landsat 7 satellite with the goal of maintaining continuity of Landsat-type data beyond the projected Landsat 6 end-of-life.

(3) Fostering the development of advanced remote sensing technologies, with the goal of reducing the cost and increasing the performance of future Landsat-type satellites to meet U.S. government needs, and potentially, enabling substantially greater opportunities for commercialization.

(4) Seeking to minimize the cost of Landsat-type data for U.S. government agencies and to provide data for use in global change research in a manner consistent with the Administration's Data Management for Global Change Research Policy Statements.

(5) Limiting U.S. government regulations affecting private sector remote sensing activities to only those required in the interest of national security, foreign policy, and public safety.

(6) Maintaining an archive, within the United States, of existing and future Landsat-type data.

(7) Considering alternatives for maintaining continuity of data beyond Landsat 7.

b. These strategy elements will be implemented within the overall resource and policy guidance provided by the President.

III. Implementing Guidelines

a. The Department of Commerce will:

(1) Complete and launch Landsat 6.

(2) In coordination with OMB, arrange for the continued operation of Landsat satellites 4 and 5 until Landsat 6 becomes operational.

b. The Department of Defense and the National Aeronautics and Space Administration will:

(1) Develop and launch a Landsat 7 satellite of at least equivalent performance to replace Landsat 6 and define alternatives for maintaining data continuity beyond Landsat 7.

(2) Prepare a plan by March 1, 1992, which addresses management and funding responsibilities, operations, data archiving and dissemination, and commercial considerations associated with the Landsat program. This plan will be coordinated with other U.S. Government agencies, as appropriate, and reviewed by the National Space Council.

(3) With the support of the Department of Energy and other appropriate agencies, prepare a coordinated technology plan that has as its goals improving the performance and reducing the cost for future Landsat-type remote sensing systems.

c. The Department of the Interior will continue to maintain a national archive of Landsat-type remote sensing data.

d. Affected agencies will identify funds, within their approved fiscal year 1993 budget, necessary to implement this strategy.

IV. Reporting Requirements

U.S. government agencies affected by these strategy guidelines are directed to report by March 15, 1992, to the National Space Council on the implementation of this strategy.

George Bush

The White House
Washington

MARCH 9, 1992

NATIONAL SPACE POLICY DIRECTIVE 6

MEMORANDUM FOR THE VICE PRESIDENT
THE SECRETARY OF STATE
THE SECRETARY OF THE TREASURY
THE SECRETARY OF DEFENSE
THE SECRETARY OF THE INTERIOR
THE SECRETARY OF AGRICULTURE
THE SECRETARY OF COMMERCE
THE SECRETARY OF TRANSPORTATION
THE SECRETARY OF ENERGY
CHIEF OF STAFF TO THE PRESIDENT
DIRECTOR OF THE OFFICE OF MANAGEMENT AND BUDGET
THE ASSISTANT TO THE PRESIDENT FOR NATIONAL SECURITY AFFAIRS
THE ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY POLICY
THE DIRECTOR OF CENTRAL INTELLIGENCE
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SUBJECT: Space Exploration Initiative

I. Introduction

I have approved the next in a series of steps to be taken by the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), the Department of Energy (DOE), and other federal agencies regarding the planning for, and conduct of, the nation's Space Exploration Initiative (SEI) which includes both Lunar and Mars elements, manned and robotic missions and supporting technology. This series of steps augments previous Presidential directives and recognizes the recommendations of both the Advisory Committee on the Future of the U.S. Space Program and the SEI Synthesis Group. The exploration of space is one of the fundamental goals of the U.S. civil space program. The SEI objectives, which build upon previous accomplishments, as well as upon existing programs, include a return to the moon - this time to stay - and human expeditions to Mars. In addition, the objectives will provide a strategic framework for the conduct of the U.S. civil space program and will help focus investments in many areas of goal-oriented research and development by government, industry and academia. Consistent with the Commercial Space Policy, this framework is also intended to encourage private sector activities which augment or support the SEI objectives.

NASA is the principal implementing agency for the SEI. DOD and DOE, as participating agencies, will have major roles in support of the SEI in the conduct of technology development and concept definition. Other U.S. government agencies are encouraged to participate by developing activities supportive of the SEI.

II. Exploration Responsibilities & Actions

To establish a firm foundation and clear direction for the SEI, the following actions shall be undertaken immediately:

(a) NASA shall establish an exploration office headed by the Associate Administrator for Exploration and staffed by NASA and representatives from other participating agencies. The Associate Administrator shall be responsible for architecture and mission studies, planning, and program execution, as well as the definition of resulting requirements for research, technology, infrastructure, mission elements and program implementation. As director of the exploration office, the Associate Administrator shall prepare an annual status report. The NASA Administrator shall present this report to the National Space Council.

(b) Working with participating agencies, NASA's Associate Administrator for Exploration shall develop a strategic plan for the SEI to establish the basis for integrating existing and future SEI-related activities. This plan shall address research, technology development and operations and identify the relationships between the SEI mission elements and the U.S. space infrastructure.

(c) A Steering Committee for Space Exploration shall be established, chaired by NASA's Associate Administrator for Exploration, and shall include representation from participating agencies. The Committee shall be the senior interagency forum for coordinating organizational interfaces, reports, plans and activities, and SEI-related programs and budgets; and for identifying those issues requiring consideration by the National Space Council. The Department of State shall participate in any meetings of the Committee related to international cooperations or other international activity.

III. Exploration Guidelines

To insure that necessary preparatory activities are accomplished, the following steps shall be taken:

(a) The participating agencies shall address critical, long-lead research and technology development activities which are supportive of the exploration strategic plan.

(b) The Department of Commerce and other appropriate agencies shall encourage the development of SEI-related proposals which foster private sector investments, ownership and operation of space-related projects and ventures, as well as promote U.S. economic competitiveness. These agencies shall seek increased cooperation with the private sector through mechanisms such as technology transfer agreements, cooperative research and development agreements, and consortia, as appropriate.

(c) Exploration requirements shall be incorporated into the evolutionary plans for the new national launch system.

(d) NASA, DOD, and DOE shall continue technology development for space nuclear power and propulsion while ensuring that these activities are performed in a safe and environmentally acceptable manner consistent with existing laws and regulations, treaty obligations and agency mission requirements.

(e) NASA and appropriate participating agencies shall implement a definitive life science program in support of the human exploration of the Moon and Mars.

(f) All participating agencies should include space exploration in their respective educational programs. In addition, participating agencies shall take advantage of university research capabilities and cooperative education programs in SEI-related activities.

(g) International cooperation in this endeavor is feasible and could offer significant benefits to the United States, subject to the satisfaction of national security, foreign policy, scientific and economic interests.

(h) Expanding on individual agency efforts to improve and streamline acquisition procedures, the Associate Administrator for Exploration, and participating agencies, shall work with the Office of Management and Budget and the Office of Federal Procurement Policy to develop improved U.S. government procurement practices available for SEI acquisition.

(i) The exploration office shall seek innovative ideas by encouraging input from all sectors of American society.

IV. Reporting Requirements

(a) By November 1992, the first annual status report shall be presented to the National Space Council. It shall address options for exploration architectures and initial capabilities.

(b) The initial version of the Strategic Plan for the Space Exploration Initiative shall be presented to the National Space Council by April 1992, and updated regularly, thereafter. The initial version shall focus on technology development and alternate mission architectures.

George Bush

The White House
Office of the Press Secretary

For Immediate Release JUNE 5, 1992

STATEMENT BY THE PRESS SECRETARY

President Bush last week approved a National Space Policy Directive establishing a focussed national effort to improve the world's ability to detect and document changes in the Earth, especially the global climate.

This policy directive, which was developed by the National Space Council chaired by Vice President Quayle:

— Establishes a comprehensive, multi-agency effort to collect, analyze, and archive space-based observations on global change. This Space-based Global Change Observation System (S-GCOS) will be led by NASA with participation from other government agencies.

— Directs that NASA's Earth Observing System (EOS) be developed using small and intermediate sized satellites. Through the use of advanced technology and reduced design complexity, these satellites can be acquired more quickly and at less cost than previously planned. This will allow the timetable for obtaining critical data on global change to be accelerated.

— Assigns global change observation functions, including the development of technology, the collection of data, and the archiving of information, to NASA and the Departments of Energy, Commerce (NOAA), Interior and Defense.

— Encourages international cooperation in global change observation from space and directs the Department of State to provide support to the implementing Agencies.

This directive augments previous Presidential directives and recognizes the recommendations of the Earth Observing System Engineering Review Panel.

# # #

Attachment

SPACE-BASED GLOBAL CHANGE OBSERVATION

I. Introduction

The U.S. Global Change Research Program (USGCRP), is a key component of the nation's overall approach to global stewardship and is one of the nation's highest priority science programs. This program's goal is to provide a sound scientific basis for developing national and international policy relating to natural and human-induced changes in the Earth system. The ultimate success of the USGCRP depends upon an integrated set of ground- and space-based observation and research programs. The United States is planning and implementing a series of satellite missions that include NASA's Mission to Planet Earth, related environmental satellites, and activities of other agencies to provide these global observations for the next several decades. For the purposes of this document, these systems are collectively referred to as the Space-based Global Change Observation System (S-GCOS).

II. Objectives

a. *General*

The Space-based Global Change Observation System will provide space-based global observations which together with other observations and studies, coordinated through the U.S. Global Change Research Program, will provide the scientific information to help understand the Earth system.

b. *Specific*

In support of the USGCRP the S-GCOS shall:

1. Improve our ability to detect and document changes in the global climate system to determine, as soon as possible, whether there is global warming or other potentially adverse global environmental changes; and, if changes are detected, determine the magnitude of these changes and identify their causes.

2. Provide data to help identify and understand the complex interactions that characterize the Earth system in order to anticipate changes and differentiate between human-induced and natural processes.

3. Provide for a data system to manage the information collected by S-GCOS as an integral part of the Global Change Data and Information System, consistent with the USGCRP data policy.

4. Provide for the development and demonstration of new space-based remote sensing technologies for global change observation and identify candidate technologies for future operational use.

III. Implementing Actions

This directive provides guidance to agencies developing, deploying, operating or supporting S-GCOS elements to acquire and manage relevant observations and data sets for the USGCRP.

a. *International Cooperation*

It is recognized that the goals and objectives of the U.S. Global Change Research Program can best be achieved through the mutually-reinforcing research of all nations and many organizations and programs which require a large measure of bilateral and multilateral cooperation. Accordingly, participating agencies may explore, in accordance with this directive and established procedures, international cooperation in space-based global change observation.

b. *Interagency Coordination*

Space-based Global Change Observation System activities are conducted in the context of the USGCRP. The Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), through its Committee on Earth and Environmental Sciences (CEES), is responsible for developing and coordinating the USGCRP, and for the activities and requirements of the USGCRP and, therefore, for the Space-based Global Change Observation System. All S-GCOS agencies shall participate with other USGCRP agencies and the CEES in the development and coordination of the Space-based Global Change Observation System Program Plan. The provision, management, and exchange of data will be a key element of the USGCRP.

The CEES will coordinate the interagency development of the Global Change Data and Information System (GCDIS) which integrates appropriate observations, regardless of platform basing mode or orientation of data (land, oceanographic, atmospheric, or space). All agencies involved with S-GCOS will participate with other USGCRP agencies in planning for the GCDIS, with a goal of maximizing the system's interoperability. Data sets intended for the GCDIS shall be responsive to the requirements of, and be accessible to, global change scientists and U.S. Government authorized research and operational users.

c. *National Aeronautics and Space Administration (NASA)*

The National Aeronautics and Space Administration is the lead agency for planning Space-based Global Change Observation System activities, and is responsible for developing and operating the NASA component of the S-GCOS. This component shall be developed to provide maximum program flexibility within budget constraints. As part of the USGCRP, NASA shall:

1. Lead the development and preparation of a coordinated interagency Space-based Global Change Observation System Program Plan, to be delivered to the National Space Council (NSpC), National Security Council (NSC), the Office of Science and Technology Policy (OSTP), and the Office of Management and Budget (OMB) by the CEES through FCCSET. This plan will guide agencies' S-GCOS activities.

2. Continue with the Mission to Planet Earth by conducting the ongoing development, operation, and scientific use of instruments and satellites designed to observe and monitor processes that govern key aspects of global environmental change.

3. As part of the Mission to Planet Earth, develop the Earth Observing System (EOS), comprised of intermediate and small sized satellites as recommended by the EOS Engineering Review Panel.

4. Plan and develop, in an incremental and evolutionary manner, the EOS Data and Information System (EOSDIS), which is the NASA part of the data and information system for S-GCOS. This data and information system shall be compatible with other parts of the USGCRP Global Change Data and Information System, and able to incorporate, as appropriate, currently available Earth observations, such as those from Landsat, and provide an active archive for S-GCOS system data sets. Prototype versions of this system, using existing Earth observations, shall be constructed to demonstrate system utility and functions.

5. Develop new instruments and space systems for global change monitoring, utilizing technologies from NASA and other S-GCOS agencies. A plan for related NASA research and development activity shall be integral to the interagency coordinated Space-based Global Change Observation System Program Plan.

d. *Department of Energy (DOE)*

The Department of Energy shall participate with NASA and the other appropriate S-GCOS agencies in developing satellite systems to maintain data continuity for the understanding of the Earth's radiation budget, starting in 1995, consistent with the Space-based Global Change Observation System Program Plan.

The DOE shall participate with other S-GCOS agencies in conducting research and development for advanced technologies that can offer promise of increased performance and/or lower cost for advanced long-term global change monitoring systems. A plan for related DOE research and development activity shall be integral to the interagency coordinated Space-based Global Change Observation System Program Plan.

e. *Department of Defense (DoD)*

The participation of the Department of Defense in the Space-based Global Change Observation System shall consist of related activities derived from current and planned DoD programs. DoD, in cooperation with the Director of Central Intelligence, as appropriate, will identify those technologies and programs that support the S-GCOS and shall seek to make appropriate technology and data from those programs available. DoD may also seek to identify and take advantage of S-GCOS programs and capabilities, as appropriate.

f. *Department of Commerce (DOC)*

The Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), shall participate in the collection, processing, archiving, retrieval, and use of oceanic- and atmospheric-oriented data and shall, consistent with the Space-based Global Change Observation System Program Plan, provide for the permanent archiving, management, access, and distribution of oceanic and atmospheric Earth science data sets for global change research, including data sets obtained by the S-GCOS. DOC/NOAA shall work with other appropriate agencies to transition, as appropriate systems, technology, and/or sensors developed for use in the S-GCOS to operational use. The Space-based Global Change Observation System Program Plan shall include a discussion of the criteria related to the desirability and economic feasibility of transitioning specific S-GCOS assets to operational use.

g. *Department of the Interior*

The Department of the Interior shall assist in the collection, processing, archiving, retrieval, and use of land-oriented data and shall, consistent with the Space-based Global Change Observation System Program Plan, provide for the permanent archiving, management, access, and distribution of land-oriented Earth science data sets for global change research, including data sets obtained by S-GCOS.

h. *Department of State*

The Department of State has a role in Space-based Global Change Observation with respect to international agreements, significant activities or arrangements with foreign countries, international organizations, or commissions where the United States and one or more foreign countries are members. Prior to discussions between participating agencies and foreign entities that could reasonably be expected to lead to such agreements, activities, or arrangements, the Department of State shall be consulted and, as appropriate, shall coordinate interagency review of the proposed U.S. position to ensure consistency with U.S. foreign policy, national security, and economic interests, and satisfaction of applicable legal requirements. This shall not affect the ability of participating agencies to explore, in accordance with established procedures, scientific, technical, and programmatic aspects of proposed international cooperation that do not involve commitments or foreign policy concerns.

IV. Reporting Requirements

a. NASA shall lead the preparation of a coordinated and integrated interagency Space-based Global Change Observation System Program Plan that shall be forwarded by the CEES through FCCSET to the NSpC, NSC, OSTP, and OMB not later than July 1, 1992. This plan shall address the S-GCOS architecture, existing and planned S-GCOS satellite systems, technology development activities, sensor suites, launch systems, supporting agency contributions and the data and information systems.

b. Each March, FCCSET/CEES shall prepare and forward a Space-based Global Change Observation System Program Report on the progress and accomplishments of the S-GCOS to the NSpC, NSC, OSTP, and OMB. The Space-based Global Change Observation System Program Plan will meet this requirement for 1992.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE RUSSIAN FEDERATION CONCERNING COOPERATION IN THE EXPLORATION AND USE OF OUTER SPACE FOR PEACEFUL PURPOSES

The United States of America and the Russian Federation, hereinafter referred to as the Parties;

Considering the role of the two States in the exploration and use of outer space for peaceful purposes;

Desiring to make the results of the exploration and use of outer space available for the benefit of the peoples of the two states and of all peoples of the world;

Considering the respective interests of the Parties in the potential for commercial applications of space technologies for the general benefit;

Taking into consideration the provisions of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, and other multilateral agreements regarding the exploration and use of outer space to which both States are Parties;

Expressing their satisfaction with cooperative accomplishments in the fields of astronomy and astrophysics, earth sciences, space biology and medicine, solar system exploration and solar terrestrial physics, as well as their desire to continue and enhance cooperation in these and other fields;

Have agreed as follows:

Article I

The Parties, through their implementing agencies, shall carry out civil space cooperation in the fields of space science, space exploration, space applications and space technology on the basis of equality, reciprocity and mutual benefit.

Cooperation may include human and robotic space flight projects, ground-based operations and experiments and other activities in such areas as:

— Monitoring the global environment from space;

— Space Shuttle and Mir Space Station missions involving the participation of U.S. astronauts and Russian cosmonauts;

— Safety of space flight activities;

— Space biology and medicine; and,

— Examining the possibilities of working together in other areas, such as the exploration of Mars.

Article II

For purposes of developing and carrying out the cooperation envisaged in Article I of this Agreement, the Parties hereby designate, respectively, as their principal implementing agencies the National Aeronautics and Space Administration for the United States and the Russian Space Agency for the Russian Federation.

The Parties may designate additional implementing agencies as they deem necessary to facilitate the conduct of specific cooperative activities in the fields enumerated in Article I of this Agreement.

Each of the cooperative projects may be the subject of a specific written agreement between the designated implementing agencies that defines the nature and scope of the project, the individual and joint responsibilities of the designated implementing agencies related to the project, financial arrangements, if any, and the protection of intellectual property consistent with the provisions of this Agreement.

Article III

Cooperative activities under this Agreement shall be conducted in accordance with national laws and regulations of each party, and shall be within the limits of available funds.

Article IV

The Parties shall hold annual consultations on civil space cooperation in order to provide a mechanism for government-level review of ongoing bilateral cooperation under this Agreement and to exchange views on such various space matters. These consultations could also provide the principal means for presenting proposals for new activities falling within the scope of this Agreement.

Article V

This Agreement shall be without prejudice to the cooperation of either Party with other states and international organizations.

Article VI

The Parties shall ensure adequate and effective protection of intellectual property created or furnished under this Agreement and relevant agreements concluded pursuant to Article II of this Agreement. Where allocation of rights to intellectual property is provided for in such agreements, the allocation shall be made in accordance with the Annex attached hereto which is an integral part of this Agreement. To the extent that it is necessary and appropriate, such agreements may contain different provisions for protection and allocation of intellectual property.

Article VII

This Agreement shall enter into force upon signature by the Parties and shall remain in force for five years. It may be extended for further five-year periods by an exchange of diplomatic notes. This Agreement may be terminated by either Party on six months written notice, through the diplomatic channel, to the other Party.

DONE at Washington, in duplicate, this seventeenth day of June, 1992, in the English and Russian languages, both texts being equally authentic.

FOR THE UNITED STATES OF AMERICA: FOR THE RUSSIAN FEDERATION:

George Bush Boris Yeltsin

ANNEX: INTELLECTUAL PROPERTY

Pursuant to Article VI of this Agreement:

The Parties shall ensure adequate and effective protection of intellectual property created or furnished under this Agreement and relevant agreements concluded pursuant to Article II of this Agreement. The Parties agree to notify one another in a timely fashion of any inventions or copyrighted works arising under this Agreement and to seek protection for such intellectual property in a timely fashion. Rights to such intellectual property shall be allocated as provided in this Annex.

I. SCOPE

a. This annex is applicable to all cooperative activities undertaken pursuant to this Agreement, except as otherwise specifically agreed by the Parties or their designees.

b. For purposes of this Agreement, "intellectual property" shall have the meaning found in Article 2 of the convention establishing the World Intellectual Property Organization, done at Stockholm, July 14, 1967.

c. This Annex addresses the allocation of rights, interests, and royalties between the Parties. Each Party shall ensure that the other Party can obtain the rights to intellectual property allocated in accordance with the Annex, by obtaining those rights from its own participants through contracts or other legal means, if necessary. This Annex does not otherwise alter or prejudice the allocation between a Party and its nationals, which shall be determined by that Party's laws and practices.

d. Disputes concerning intellectual property arising under this Agreement should be resolved through discussions between the concerned participating institutions or, if necessary, the Parties or their designees. Upon mutual agreement of the Parties, a dispute shall be submitted to an arbitral tribunal for binding arbitration in accordance with the applicable rules of international law. Unless the Parties or their designees agree otherwise in writing, the arbitration rules of UNCITRAL shall govern.

e. Termination or expiration of this Agreement shall not affect rights or obligations under this Annex.

II. ALLOCATION OF RIGHTS

a. Each Party shall be entitled to a non-exclusive irrevocable, royalty-free license in all countries to translate, reproduce, and publicly distribute scientific and technical journal articles, reports, and books directly arising from cooperation under this Agreement. All publicly distributed copies of a copyrighted work prepared under this provision shall indicate the names of the authors of the work unless an author explicitly declines to be named.

b. Rights to all forms of intellectual property, other than those rights described in Section II(a) above, shall be allocated as follows:

1. Visiting researchers and scientists visiting primarily in furtherance of their education shall receive intellectual property rights under the policies of the host institution. In addition, each visiting researcher or scientist named as an inventor shall be entitled to share in a portion of any royalties earned by the host institution from the licensing of such intellectual property.

2. (a) For intellectual property created during joint research with participation from the two Parties, for example, when the Parties, participating institutions, or participating personnel have agreed in advance on the scope of work, each Party shall be entitled to obtain all rights and interests in its own country. Rights and interests in third countries will be determined in agreements concluded pursuant to Article II of this Agreement. The rights to intellectual property shall be allocated with due respect for the economic, scientific and technological contributions from each Party to the creation of intellectual property. If research is not designated as "joint research" in the relevant agreement concluded pursuant to Article II of this Agreement, rights to intellectual property arising from the research shall be allocated in accordance with Paragraph IIb1. In addition, each person named as an inventor shall be entitled to share in a portion of any royalties earned by their institution from the licensing of the property.

(b) Notwithstanding Paragraph IIb2(a), if a type of intellectual property is available under the laws of one Party but not the other Party, the Party whose laws provide for this type of protection shall be entitled to all rights and interests in all countries which provide rights to such intellectual property. Persons named as inventors of the property shall nonetheless be entitled to royalties as provided in Paragraph IIb2(a).

III. BUSINESS-CONFIDENTIAL INFORMATION

In the event that information identified in a timely fashion as business-confidential is furnished or created under the Agreement, each Party and its participants shall protect such information in accordance with applicable laws, regulations, and administrative practice. Information may be identified as "business-confidential" if a person having the information may derive an economic benefit from it or may obtain a competitive advantage over those who do not have it, the information is not generally known or publicly available from other sources, and the owner has not previously made the information available without imposing in a timely manner an obligation to keep it confidential.

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