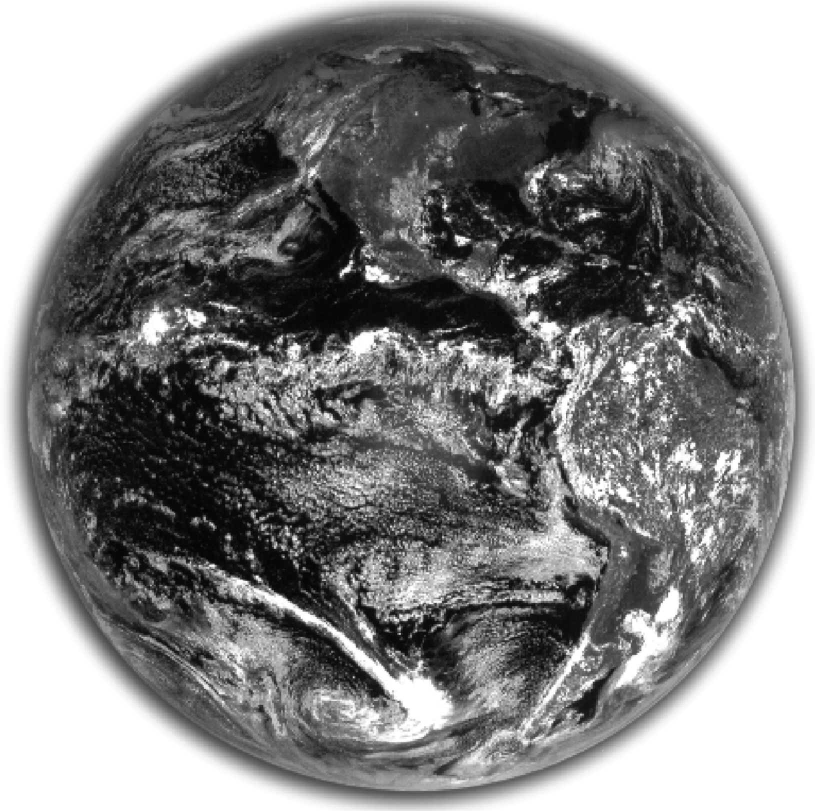
Aeronautics
and
Space Report
of the
President



Fiscal Year
1995
Activities

National Aeronautics
and Space Administration

Washington, DC 20546

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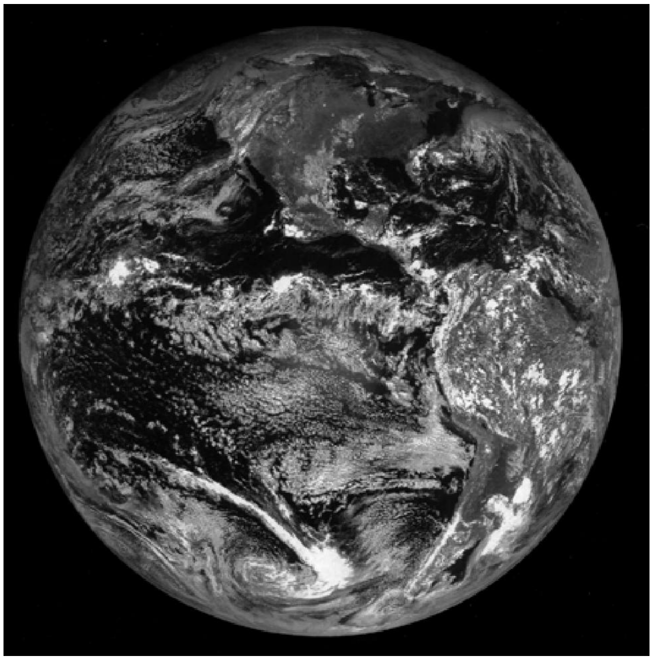
EXECUTIVE SUMMARY

The National Aeronautics and Space Act of 1958 directed the annual Aeronautics and Space Report to 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." In recent years, the reports have been prepared on a fiscal year (FY) basis, consistent with the budgetary period now used in programs of the Federal Government. This year's report covers activities that took place from October 1, 1994, through September 30, 1995.



This photo of Earth was processed by NOAA's National Environmental Satellite, Data, and Information Service.

A wide variety of aeronautics and space developments took place during FY 1995. The National Aeronautics and Space Administration (NASA) successfully completed seven Space Shuttle flights. A program highlight was the docking of the Shuttle *Atlantis* with the Russian space station *Mir*.

NASA launched three Expendable Launch Vehicles (ELV), while the Department of Defense (DoD) successfully conducted five ELV launches during the fiscal year. These launches included satellites to study space physics, track Earth's weather patterns, and support military communications. In addition, there were 12 commercial launches carried out from Government facilities that the Office of Commercial Space Transportation (OCST) within the Department of Transportation (DoT) licensed and monitored.

NASA continued the search for a next-generation space launch system with its Reusable Launch Vehicle (RLV) program. NASA hopes to develop new kinds of launch technologies that will enable significantly more affordable and reliable access to space.

In aeronautics, activities included the development of technologies to increase safety, reduce negative environmental impacts, and assist U.S. industry in becoming more competitive in the world market. Air traffic control activities focused on various automation systems to increase flight safety and enhance the efficient use of airspace.

Scientists made some dramatic new discoveries in various space-related fields. Astronomers gained new insights into the size and age of our universe, in addition to studying our solar system. Earth scientists continued to study the complex interactions of physical forces that influence our weather and environment and reached new conclusions about ozone depletion. Agencies such as the Environmental Protection Agency (EPA) as well as the Departments of Agriculture and Interior used remote-sensing technologies to better understand terrestrial changes. Microgravity researchers conducted studies to prepare for the long-duration stays of humans planned for the upcoming International Space Station (ISS).

International cooperation, particularly with Russia, occurred in a variety of aerospace areas. In addition to the Shuttle-Mir docking mission and Russian partnership on the International Space Station, U.S. and Russian personnel also continued close cooperation on various aeronautics projects.

During FY 1995, the Government released two significant interagency space policy documents that are included in this report's appendix section. The first is a memorandum of agreement among NASA, DoD, and the Department of Commerce to implement an FY 1994 policy on convergence of the Nation's civilian and military polar-orbiting environmental satellite programs. The second document is a Presidential Review Directive calling for an interagency space policy review.

National Aeronautics and Space Administration (NASA)

In the area of space science, NASA researchers made a number of exciting discoveries during FY 1995. By precisely determining distances to some nearby stars, astronomers used the refurbished Hubble Space Telescope (HST) to determine that the universe is smaller and younger than previously thought, about 10 billion years old. In our solar system, HST scientists confirmed the existence of the Kuiper Belt, a swarm of comets in the outer reaches of the solar system, and discovered the large Comet Hale-Bopp, which will pass near Earth in 1997. Astrophysicists used the Compton Gamma Ray Observatory (CGRO) to study mysterious gamma ray bursts that have been occurring throughout the sky to try to identify their origins. The Ulysses spacecraft successfully completed its passage over the northern pole of the Sun, completing the first exploration of the solar wind above its polar regions. Spartan 204, a small satellite deployed and retrieved by the Space Shuttle in February 1995, found evidence of hot coronal gas that may explain why the wind speed is so high in the solar polar regions. The Voyager and Pioneer sets of spacecraft continued their exploration of the outer edges of our solar system. The Global Geospace Science (GGS) Wind spacecraft was launched successfully in November 1994 into a path upstream of the Earth's magnetosphere, where it has been providing valuable information on the solar wind. In solar system exploration, scientists reported the discovery of a large planet orbiting the star 51 Pegasi. Astronomers also gained new insights into the evolution of stars by studying silicon carbide and aluminum oxide grains in primitive meteorites.

In the area of Earth science, NASA's Mission to Planet Earth (MTPE) program continued to make a number of significant discoveries. Scientists, who analyzed several years of data derived from satellites and aircraft, conclusively determined that human-produced chemicals are the source of at least 80 percent of the chlorine in the stratosphere, which causes Antarctic ozone depletion. In oceanographic studies, the joint U.S./French satellite TOPEX/Poseidon demonstrated a new way of precisely monitoring global mean-sea-level variations, while another satellite helped chart the role of lightning in severe storms. Data from the Landsat 5 satellite continued to prove valuable in numerous practical applications, such as forest management, earthquake and flood damage assessments, and geological explorations, in addition to various forms of environmental and global change research. MTPE scientists worked closely with their colleagues at other agencies to improve Earth science education and to approach global change from an interdisciplinary perspective. During FY 1995, NASA managers focused on a series of important reshaping exercises for MTPE and its centerpiece, the Earth Observing System (EOS) series of spacecraft, to chart the long-term implementation planning for the program. Computer specialists continued to develop the EOS Data and Information System (EOSDIS) Version 0 and identified user categories at the first EOSDIS Potential User Conference. NASA also worked closely with the National Oceanic and Atmospheric Administration (NOAA) on the Geostationary Operational Environmental Satellite (GOES) program and with NOAA and DoD on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program's triagency Integrated Program Office.

During FY 1995, engineers accomplished many of the 1993 redesign goals on the revamped International Space Station program. NASA personnel solidified their "core team" management philosophy by finalizing the $5.63 billion design and development contract with the prime contractor, Boeing, which has been collocated in the ISS program office.

The program successfully completed the first in a series of incremental design reviews, and NASA held a major design review for the Russian-supplied Functional Cargo Block (FGB). Through the end of FY 1995, contractors had delivered more than 70,000 pounds of Station flight hardware and completed the fabrication of the first U.S. element (Node 1), the Structural Test Article (Node 2), and the U.S. laboratory module. While development programs also moved forward in Canada, Japan, Russia, and the nine participating European nations, the Shuttle-*Mir* program (Phase 1) proceeded to provide operational experience, risk mitigation, technology demonstrations, and early science opportunities. In March 1995, a Russian Soyuz vehicle carried the *Mir* 18 crew to the Russian space station; this crew included U.S. astronaut Dr. Norman Thagard. In June 1995, the Space Shuttle Atlantis made the historic first docking with *Mir*; during 5 days of docked operations, astronauts conducted various experiments similar to those planned for the International Space Station. Dr. Thagard, who returned to Earth on *Atlantis* with some of the *Mir* 18 crew, stayed aboard *Mir* for 115 days, providing researchers from NASA's Office of Life and Microgravity Sciences and Applications (OLMSA) with valuable long-duration biomedical data.

In addition to Dr. Thagard's record-breaking mission, OLMSA made other significant strides in its transition toward the ISS era of orbital research. Protein crystal researchers took advantage of *Mir* to begin the longest period of protein crystal growth in space, with the placement of samples on *Mir* in June 1995 and their return to Earth in November 1995. Experiments on *Mir* identified a new technique that may allow as many as 10,000 protein crystal samples to be grown in a single Space Shuttle experiment. Protein crystals grown in orbit are already supporting drug development efforts by major pharmaceutical companies, and this recent discovery may accelerate that process. OLMSA outfitted the Russian Spektr and Priroda laboratory modules for *Mir* with more than 2,000 kilograms of research equipment; the Russian Space Agency launched Spektr on May 20, 1995. OLMSA, in consultation with prospective users in the scientific community, continued to design and prepare a series of major laboratory facilities and a glovebox facility for the International Space Station. OLMSA researchers made final preparations for the launch of the second United States Microgravity Laboratory (USML-2), a dedicated microgravity science mission that flew aboard the Space Shuttle in October 1995. OLMSA also collaborated with various researchers at the National Institutes of Health (NIH) to develop new digital imaging techniques for breast cancer detection and to exploit NASA's bioreactor technology to study the infectivity of the human immunodeficiency virus (HIV).

During FY 1995, NASA successfully completed seven Space Shuttle missions. Shuttle crews deployed payloads such as the Space Radar Laboratory-2 (SRL-2), the third Atmospheric Laboratory for Applications and Science (ATLAS-3), the first Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite (CRISTA-SPAS-1), the Shuttle Solar Backscatter Ultraviolet (SSBUV) instruments, the NASA Tracking and Data Relay Satellite (TDRS-G), the Wake Shield Facility, and the Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN). Before STS-71 (Space Transpor-tation System—71st planned mission) could achieve its historic docking with *Mir* in June 1995, STS-63 performed a close rendezvous with *Mir* in February 1995 to validate the flight operations techniques necessary for docking. In terms of Shuttle technology and operations, managers made several important changes during FY 1995. Program managers initiated a major restructuring to focus spaceflight operations under a single prime contractor. Shuttle managers pursued the development and implementation of safety and reliability improvements for the Shuttle Main Engine, while engineers continued to redesign the External Tank to improve performance.

In aeronautics, NASA's High-Speed Research program continued to focus on resolving critical environmental issues and laying the technological foundation for an economical, next-generation High-Speed Civil Transport (HSCT). NASA officials completed key agreements with Russia to use the Tu-144 supersonic transport as a testbed for HSCT development. NASA's Advanced Subsonic Technology program continued to facilitate a safe, productive global air transportation system, which includes a new generation of environmentally compatible, economical aircraft that will compete in international markets. In the advanced subsonic area, managers focused on reducing engine noise levels and on creating technologies that will improve general aviation aircraft and air traffic management. In the supersonic area, NASA's SR-71 Aircraft Testbed program conducted baseline flights for aeronautical research to assist industry in making key decisions about developing HSCT. In its High Alpha

Technology program, NASA sought to achieve a basic understanding of high angle-of-attack aerodynamics, including the effects of vectorable thrust nozzles as an advanced flight control concept. NASA also undertook important aeronautics research, using its F-18 Systems Research Aircraft, its Vertical/Short Takeoff and Landing (V/STOL) System Research Aircraft, and its F-15 testbed aircraft. Additionally, NASA continued to ensure U.S. preeminence in high-performance computing. It engaged in several projects to make the remote-sensing data of various Federal agencies available over the Internet in new, stimulating ways and to accelerate the growth of a global information infrastructure, especially for educational purposes in primary and secondary schools.

In the area of space technology, NASA explored new launch vehicle options in addition to smaller, less costly instruments and new methods for Government-industry cooperation. NASA initiated the RLV technology development and demonstration program in FY 1995, issuing Cooperative Agreement Notices for two experimental test vehicles, the X-33 and the X-34. NASA managers plan to have industry take the lead on the RLV program once it matures. NASA accelerated its aggressive effort to reduce mission costs and increase performance by developing new technologies. Of particular note, NASA tested a solar dynamic power system for future spacecraft power needs and a planetary rover, which traversed 10 kilometers under its own control. NASA released a comprehensive policy document, "Agenda for Change," which established a new way of doing business for NASA's transfer of technology to the private sector. NASA also established an Advanced Concepts office to identify and develop new, far-reaching technology concepts.

NASA personnel also continued activities in important support areas, such as space communications, safety and mission assurance, and international coordination. In space communications, engineers continued to improve the space and ground networks to provide reliable communications; NASA also consolidated some mission control and data systems facilities, which resulted in significant cost savings. NASA continued to emphasize a strong Safety, Reliability, and Quality Assurance (SR&QA) presence on current and future flight projects; specific safety activities included completing more than 30 formal independent assessments of the International Space Station, updating NASA's emergency program plan, promoting ISO (International Organization for Standardization) 9000 as NASA's standard for quality management systems, and implementing the NASA Engineering and Quality Audit program. In addition to continuing negotiations on the International Space Station, NASA international affairs personnel supported meetings of the U.S.-Russia Commission on Economic and Technological Cooperation (the "Gore-Chernomyrdin Commission"), worked with the Russian Space Agency's Scientific and Technical Advisory Council, negotiated an agreement with the Russian Ministry of Science and Technology Policy on space biomedical research, negotiated agreements on space cooperation with Ukraine, and represented NASA at United Nations discussions on orbital debris.

During FY 1995, NASA updated its Strategic Plan by adding goals for its five Strategic Enterprises (Mission to Planet Earth, Aeronautics, Human Exploration and Development of Space, Space Science, and Space Technology). This was done to provide further insight into NASA's future direction and to enable its stakeholders, customers, partners, and employees to assist NASA in achieving its mission. NASA's Strategic Plan enables it to meet new challenges and to deliver a vibrant aeronautics and space program that inspires the Nation.

Department of Defense (DoD)

A major organizational change in DoD's space activities occurred in December 1994 when the Deputy Secretary of Defense created the Deputy Undersecretary of Defense for Space position. The holder of this position reports to the Undersecretary of Defense for Acquisition and Technology (USD (A&T)). This new office is responsible for a variety of space and intelligence functions for DoD, such as policy, strategy, plans, international negotiations, interface with Congress and other executive branch agencies, and integration of space systems into the DoD force structure and weapons systems. The office also handles oversight for the following space programs: launch and support, reconnaissance and surveillance, tactical warning and attack assessment, communications (including Milstar and the new Global Broadcast System), navigation (including the space and ground segments for the Global Positioning System (GPS)), environmental monitoring, space control, and research and development. This new office consists of three smaller offices: space acquisition and management, space policy, and systems and architectures.

Another organizational change was the establishment of a new DoD Space Architect position. DoD created this position to consolidate responsibilities for DoD space missions and system architecture development into a single organization to achieve efficiencies in acquisition and future operations through program integration. The DoD Space Architect reports through the Air Force Acquisition Executive to the Defense Acquisition Executive, who is also the USD (A&T). The Deputy Undersecretary of Defense for Space, on behalf of the USD (A&T), provides departmental policy guidance and oversight to the Architect for the development of consistent, integrated space architectures. The Space Architect's specific new responsibilities include launch and satellite control and the space-related areas of tactical intelligence such as targeting; surveillance and warning; command, control, communications, and intelligence (C3I); navigation; environmental monitoring; and space control. The Deputy Secretary of Defense identified two immediate tasks for the Space Architect: (1) the integration of DoD and intelligence systems architecture planning and (2) the development of a future military satellite communications architecture encompassing core DoD, allied, civil, and commercial capabilities.

During FY 1995, space forces played an important role as a force multiplier everywhere U.S. forces were employed. In Haiti, the military deployed a space support team to advise the task force commander on the effective use of space assets, such as the Milstar I and the Ultra High Frequency (UHF) Follow-On (UFO) satellites. U.S. forces supporting United Nations efforts in Bosnia used space imagery to aid search-and-rescue teams and the Air Force's overall theater mission. Space systems also directly supported exercises in Korea, Japan, and elsewhere in Europe.

A DoD Atlas I launched the new Geostationary Operational Environmental Satellite (GOES-8) spacecraft into orbit for NOAA, and two commercial Atlas IIA rockets carried the fourth and fifth UFO satellites into orbit for DoD. The fourth UFO satellite was launched successfully on an Atlas IIA on January 28, 1995, and became operational in a geosynchronous orbit over the Pacific Ocean. On May 31, 1995, UFO-5 was launched into a geosynchronous orbit over the Indian Ocean and became operational on August 1, 1995.

The Defense Satellite Communications System (DSCS) program successfully launched its DSCS III satellite into orbit in July 1995 aboard an Atlas IIA rocket. The Defense Information Systems Agency initiated the Commercial Satellite Communications Initiative pilot program in July 1995 and awarded a contract for using commercial transponders and a network management worldwide.

In the area of launch vehicle technology, the Ballistic Missile Defense Organization (BMDO) transferred the Delta Clipper–Experimental (DC-X) program to NASA, although the Air Force's Phillips Laboratory continued to support NASA on this program. In addition, DoD managers selected four prime contractors for the Evolved Expendable Launch Vehicle (EELV) low-cost concept validation module.

DoD continued its efforts with the Department of Energy (DoE) on the Topaz international program for nuclear space power systems. This program is centered on a thermionic nuclear reactor, called the Topaz II, which was developed in the former Soviet Union.

On the Clementine mission, mission controllers successfully reestablished contact with the spacecraft in February 1995. This BMDO-sponsored project was a low-cost demonstration of a variety of new spacecraft technologies that also provided scientists with detailed new mapping information of the Moon.

DoD personnel also were active in a number of aeronautical technology programs during FY 1995. The Navy and Marine Corps continued to make progress on the V-22 tilt-rotor aircraft, and DoD supported the National Wind Tunnel Complex activities at NASA's Lewis Research Center (LeRC). Research on the X-31 program demonstrated the value of vectored thrust to advanced high-performance aircraft. The Darkstar Unmanned Aerial Vehicle (UAV) was unveiled at the contractor facility in June 1995.

In the navigation arena, GPS continued to be deployed worldwide. During FY 1995, DoD began to integrate GPS into U.S. pilots' survival radios.

DoD continued to be active in the Earth studies field during the fiscal year. The Polar Ozone and Aerosol Measurement (POAM-II) experiment on the French Satellite Pour l'Observation de la Terre (SPOT—satellite for the observation of the Earth) provided important profiles of gases in the middle atmosphere. In negotiations on the NASA/Centre Nationale d'Etudes Spatiales (CNES—the French space agency) TOPEX/Poseidon Follow-On (TPFO) mission with the Navy Geosat mission, the Navy agreed to support the NASA TPFO mission.

Department of Transportation (DoT)

Federal Aviation Administration (FAA)

In terms of air traffic control and navigation, the FAA undertook a wide variety of activities in FY 1995. The FAA's Advanced Automation System program underwent major restructuring to contain cost growth and minimize delays, and several new component systems were introduced. The FAA ordered a new digital Voice Switching and Control System for all traffic control centers, and the FAA Academy replaced 30-year-old equipment. In a significant milestone for satellite navigation, the FAA awarded a contract to build a Wide Area Augmentation System (WAAS). FAA personnel hope that the WAAS will transform national navigation from ground-based to space-based capability. The WAAS program is being designed to serve all phases of flight, including takeoff, en route, approach, and landing. During FY 1995, GPS achieved final operating capability for civil aviation usage, and the FAA continued to certify additional GPS receivers. The FAA continued to conduct flight tests for GPS nonprecision terminal approach instrument procedures at heliports, which resulted in 35 lives being saved in one year at a single trauma center test site.

The FAA required small commercial airplanes to be equipped with the Traffic Alert and Collision Avoidance System by the end of 1995. In Atlantic City, the FAA Technical Center helped develop and define a common set of air traffic control protocols for operational procedures for the New York Air Route Traffic Control Center to accommodate a reduced aircraft vertical separation standard. The FAA also worked toward the development of U.S. and international standards for controller/pilot data link communications to standardize interfaces for digital messages.

In the area of weather services, the FAA continued development of Integrated Terminal Weather Systems to provide short-range forecast and warning notices to pilots and air traffic controllers. Demonstrations of Graphical Weather Services and Traffic Information Services began in 1995 and will lead to a regional evaluation program and then a national implementation. During FY 1995, the FAA commissioned Terminal Doppler Weather Radar Systems at four test sites around the country. Engineers completed the development of the FAA's Wake Vortex Training Aid, addressing vortex issues from the viewpoint of both the pilot and the air traffic controller, and distributed several thousand copies to the FAA and industry. The FAA also worked closely with British officials to analyze aircraft separation data relevant to wake vortices.

Flight safety and security were two additional areas of considerable activity for the FAA during FY 1995. In particular, the FAA worked to find environmentally acceptable fire extinguishing systems without halon. The FAA continued its comprehensive Airport Pavement Research Program and its work with NASA's Langley Research Center (LaRC) in analyzing aircraft structural safety through the use of Langley's crash impact research facility. Internationally, the FAA participated in the development of an Air Accident Investigation Tool with the Civil Aviation Authority in England. The FAA continued to research various technologies and methodologies to mitigate and prevent catastrophic failure to aircraft. In the area of security technology, the FAA certified the first Explosive Detection System for detecting bulk explosives in checked baggage.

During FY 1995, the FAA continued its efforts to improve human performance in the national airspace system through its research and development program. FAA personnel also developed a prototype automated performance measurement system to provide objective measures of crew and aircraft performance. Additionally, the FAA produced a *Human Factors Guide for Aviation Maintenance*, which provided maintenance managers with established principles of job design in a reference work suitable for daily use.

The FAA collaborated with NASA on a variety of projects relating to general aviation, from aircraft noise and emission reductions to innovative aircraft design. In the area of noise reduction, the two agencies reported to Congress their progress on technologies for subsonic aircraft, particularly propeller-driven airplanes and rotorcraft. The FAA also participated in a NASA study to develop a scientific basis for assessing the impact of aircraft emissions on the environment, particularly on the ozone layer and global climate change. Cockpit display and control technologies and civilian tiltrotor aircraft were two other topics of FAA-NASA cooperation. Near the end of the fiscal year, the FAA and NASA signed a Memorandum of Understanding (MOU) on Airspace System User Operational Flexibility and Productivity, which initiates joint research and development activities to improve the efficiency of the Nation's airspace system.

Office of Commercial Space Transportation (OCST)

Since OCST was established in 1984, its responsibilities have been to license commercial space launches and the operation of launch facilities and to encourage commercial space launches by the private sector. Twelve commercial space launches were conducted by U.S. launch operators under licenses granted by OCST during FY 1995. OCST issued a payload determination for the Multiple Experiment to Earth Orbit and Return reentry vehicle, the first attempt at a ground-initiated reentry of an orbital spacecraft by a commercial operator. In connection with the amended Commercial Space Launch Act, OCST processed more than a dozen maximum probable-loss determinations based on the actual risks associated with proposed launch activities during the fiscal year. OCST also continued a program to encourage and facilitate the development of voluntary industry standards for launch safety. A major priority for OCST during this fiscal year was the updating and "reinventing" of its original 1988 regulations.

A major policy accomplishment by OCST for FY 1995 was the development of the Implementation Plan for the National Space Transportation Policy that was adopted the previous fiscal year. OCST also participated in several interagency efforts on space policy led by the White House Office of Science and Technology Policy.

OCST experts also supported the U.S. Trade Representative's (USTR) office in its negotiations for a new space launch trade agreement between the United States and the People's Republic of China. This agreement was signed into force on March 3, 1995. OCST also supported a USTR-led delegation to establish a commercial space launch trade agreement between the United States and Ukraine.

In the area of launch vehicle technology, the OCST Director provided technical assistance and policy analysis as a member of the DoD's Source Selection Advisory Board for the EELV program. Similarly, OCST's staff provided technical and analytical support to a NASA-led review of the RLV technology program.

Regarding orbital debris, OCST contributed significantly to the interagency effort to develop policy on space orbital debris for the U.S. delegation to the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). To support pending and anticipated applications for licenses to launch large constellations of communications satellites in low-Earth orbit (LEO), OCST personnel researched collision risk and the effects of service disruptions caused by collision.

Department of Commerce (DoC)

Within DoC, the Office of Air and Space Commercialization (OASC) ensures that U.S. commercial space interests are represented in the formulation of space-related Government policies and agreements. OASC activities for FY 1995 included contributing to the Clinton administration's policy on the use of foreign excess ballistic missiles, helping negotiate launch trade agreements with China and Ukraine, implementing the administration's commercial remote-sensing policy, and serving on the Common Spacelift Requirements Working Group called for in the National Space Transportation Policy. Also in FY 1995, OASC supported the revision of the National Space Policy, the development of a U.S. GPS policy, and a review of further guidance on the Government's use of remote-sensing satellite data.

The International Trade Administration's Office of Aerospace also contributed to the Clinton administration's new policy on the commercial use of Russian excess ballistic missiles and negotiations of commercial space launch agreements with China and Ukraine. In addition, the Office of Aerospace pressed for expanded export opportunities for U.S. aircraft manufacturers through negotiations in the World Trade Organization (WTO). The Office of Aerospace participated in negotiations for a major coproduction project, the Russian passenger aircraft IL-96M/T, which could set the tone for future ventures with Russia. To promote the export of U.S. aerospace products, the Office of Aerospace led numerous trade missions, managed the U.S. pavilion at the Paris Air Show, and operated "Aerospace Product Literature Centers" at major international air shows.

The National Oceanographic and Atmospheric Administration (NOAA), another Commerce unit, also was active in space activities during FY 1995. On December 30, 1994, NOAA-J (NOAA-14) of the Polar-orbiting Operational Environmental Satellite (POES) series was launched successfully. In May 1995, the newest in the series of Geostationary Operational Environmental Satellites

(GOES-J) was launched into orbit for NOAA as GOES-9; GOES-8 was declared fully operational in June 1995. In May 1995, NOAA, NASA, and DoD finalized a Memorandum of Agreement regarding the triagency convergence planning effort. NOAA continued to rely on Landsat-5 to provide regular data about the Earth's renewable and nonrenewable resources. NOAA also continued its support for the international satellite-aided search-and-rescue program known as Cospas-Sarsat by signing a new intergovernmental agreement. In the area of atmospheric studies, NOAA satellites measured unusually low ozone levels over parts of the Northern Hemisphere. NOAA scientists also integrated ocean data from a variety of sources in the NOAA Satellite Ocean Remote Sensing program. Finally, NOAA continued negotiations with its European partners on a joint polar system of satellites.

As the lead advising agency for Government telecommunications issues, the National Telecommunications and Information Administration (NTIA) undertook a number of policy initiatives regarding satellites and other space-based communications systems. Specifically, NTIA provided policy guidance on the restructuring of INTELSAT and INMARSAT. While the Federal Communications Commission (FCC) continued to regulate the electromagnetic spectrum for commercial users, NTIA administered the spectrum, helping firms clear unexpected regulatory hurdles. NTIA engineers also were instrumental in developing a national plan to augment the navigation signals of GPS for the benefit of a wide variety of civilian and commercial users.

Scientists and engineers at the National Institute of Standards and Technology (NIST), another entity of DoC, performed a wide variety of research in measurement science and technology in support of aeronautics and space activities during FY 1995. These research areas covered a wide range of topics, including global atmospheric science, the Hubble Space Telescope, materials science, and microgravity science.

Department of Energy (DoE)

In FY 1995, DoE continued its work in the fabrication of three General Purpose Heat Sources–Radioisotope Thermoelectric Generators (GPHS-RTG) and 157 Radioisotope Heater Units (RHU) for NASA's upcoming Cassini mission to Saturn. DoE took delivery in 1995 of 4.2 kilograms of Russian-produced Plutonium-238 (Pu-238) to supplement its existing inventory; this material can be used to fuel smaller, more efficient spacecraft for future planetary exploration missions. DoE agreed to provide three Lightweight Radioisotope Heater Units (LWRHU) from its inventory (these are actually spares from the Galileo and Ulysses missions) for NASA's upcoming launch of the Mars Pathfinder spacecraft. For NASA's Pluto Express mission, DoE studied advanced converter technologies to provide high efficiency and lightweight power sources.

DoE staff also supported the Defense Nuclear Agency in managing the Topaz international program. Developed by the Russians, the Topaz is a nuclear reactor power source for spacecraft; unlike RTGs, it has moving parts like a ground nuclear powerplant. In conjunction with the Jet Propulsion Laboratory (JPL) and the Air Force, DoE explored the use of bimodal (power/propulsion) space reactor systems, especially in support of NASA's New Millennium spacecraft program. Finally, DoE's Sandia and Los Alamos National Laboratories continued to provide nuclear explosion sensors for integration onto DoD GPS and defense support program spacecraft.

Department of the Interior (DoI)

DoI applied GPS and other remote-sensing technologies from satellites and aircraft in a variety of research and operational programs in FY 1995. DoI continued to cooperate with DoD to use the Navstar GPS Precise Positioning Service (PPS). DoI bureaus purchased approximately 180 precision lightweight GPS receivers in 1995 and used the PPS for a wide range of mapping, inventory, monitoring, and research activities. The Minerals Management Service used GPS in Federal offshore waters to determine the positions of occupied and abandoned oil and gas platforms, wellheads, and pipelines. The Office of Surface Mining Reclamation and Enforcement expanded its use of the Navstar GPS to locate water and mine overburden sampling sites for the Appalachian Clean Streams Initiative, a public-private partnership aimed at predicting, preventing, and mitigating acid drainage from abandoned coal mines.

Other units of DoI also used satellite data for a variety of purposes. The Bureau of Indian Affairs (BIA) used remotely sensed data and GPS to conduct natural resource inventories, image mapping projects, Geographic Information System (GIS) data base development, and training to support the BIA Indian Integrated Resource

Information Program. The Bureau of Land Management used satellite data, aerial photographs, and GPS technology to monitor the health of public lands and the effectiveness of ecosystem-based management practices. The Bureau of Mines continued to use Landsat and airborne multispectral scanner data to evaluate the actual and potential impacts of mine wastes on abandoned noncoal mine lands in Colorado. The National Biological Service (NBS), in partnership with the U.S. Fish and Wildlife Service (FWS), continued to use data from the Landsat-5 Thematic Mapper instrument and SPOT in the Gap Analysis Program for identifying biological resources on lands in 40 states that are not adequately protected and managed to preserve biological diversity. The FWS used computerized mapping, aerial photography, and satellite data to support ecosystems management and data-sharing initiatives with Federal, State, and local agencies and private industry; its National Wetlands Inventory has produced wetlands maps of more than 80 percent of the United States and its territories. The National Park Service worked with the NBS on several prototype mapping projects as part of a comprehensive, multiyear vegetation mapping program in more than 235 units of the National Park System.

U.S. Geological Survey (USGS) personnel have collected, processed, and archived more than 60,000 daily Advanced Very High Resolution Radiometer (AVHRR) observations since the beginning of the Global Land 1-kilometer AVHRR Pathfinder project in cooperation with NASA, NOAA, and the European Space Agency (ESA). USGS scientists produced a year-long time series of cloud-free vegetation index composites for the Western Hemisphere, Africa, and Europe. USGS scientists helped their NASA colleagues make final preparations for the Galileo spacecraft mission, which reached Jupiter in December 1995. USGS personnel also worked closely in planning and developing several other planetary science programs, such as the Mars Global Surveyor, Mars Pathfinder, and the Cassini missions.

U.S. Department of Agriculture (USDA)

At USDA, the Foreign Agricultural Service used remote-sensing imagery to assess and monitor domestic and foreign agricultural crop yields. The Agricultural Research Service used remote-sensing data to advance the development of precision farming, map regional vegetative disease, assess soil salinity on crops, and monitor changes in animal habitats, crop growth, and moisture conditions. The National Agricultural Statistics Service used remote-sensing data to stratify land for area-based statistical samples, to estimate planted crop area, to create crop-specific, land-cover data layers for GIS's, and to assess crop conditions. Sharing costs with other Federal and State agencies, the Natural Resources Conservation Service (NRCS) acquired aerial photography through the National Aerial Photography Program (NAPP). The NRCS used NAPP as a source of imagery to produce digital orthophotography in support of its soil survey program and as a technical assistance tool in helping landowners and communities conserve and protect our natural resources on private lands. The Forest Service used remotely sensed data to protect and manage the 191 million acres of land comprising the National Forest System.

Federal Communications Commission (FCC)

The FCC coordinated and registered launches of spacecraft for INTELSAT, a consortium of more than 130 countries that own and operate the world's most extensive global communications satellite system. INTELSAT 703, 704, 705, and 706 were all launched during FY 1995. The FCC also authorized FY 1995 launches of two global communications satellites by PanAmSat, the first private company to provide global satellite services. Similarly, the FCC authorized the November 1994 launch of the Orion I communications satellite. In January 1995, the FCC allocated spectrum for satellite Digital Audio Radio Services (DARS). This action is the first step toward providing the American public with new multichannel, multiformat digital radio service with sound quality equivalent to compact disks. Overall, the FCC continued to regulate non-Government uses of the communications spectrum.

U.S. Environmental Protection Agency (EPA)

EPA, primarily through its National Exposure Research Laboratory (NERL), conducted research and used remote-sensing as part of an overall environmental monitoring program. NERL completed approximately 100 site-characterization projects, using aerial photography, in FY 1995. In studying the feasibility of remedial actions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPA used large-scale aerial photographs. EPA engineers and scientists also analyzed these aerial photos to support site selection and monitoring at hazardous waste facilities operated under the Resource Conservation and Recovery Act (RCRA). NERL also conducted research in large-area land cover mapping and has produced a land cover data set for EPA Region 3.

In addition, EPA developed and used remote-sensing systems to support enforcement of the Clean Water Act. During FY 1995, EPA used remote-sensing data in a GIS that provided useful analytical background for various environmental programs. Overall, EPA used aerial photographs and satellite data in a variety of pollution-prevention, global change, and ecosystem-monitoring studies.

National Science Foundation (NSF)

Researchers who were supported by the National Science Foundation (NSF) and who used NSF-sponsored facilities made a number of advances in astronomy and space physics during FY 1995. Observations from the Very Long Baseline Array provided observational proof of the existence of a black hole in the center of the galaxy NGC 4258. Scientists using observations from the Kitt Peak National Observatory analyzed the shape and age of the Galactic Halo (an enigmatic distribution of older stars that appears key to understanding the formation of our galaxy), concluding that the formation of the Milky Way may have been the product of both the collapse of a protogalaxy and the capture and shredding of neighboring dwarf galaxies. Observations from the Cerro-Tololo Inter-American Observatory provided for an improved understanding of the origins of the Magellanic Stream (a large filament of neutral hydrogen gas from the Milky Way's radio emission that originates at the Small Magellanic Cloud, a Milky Way satellite dwarf galaxy, and extends almost one-third of the way around the sky). Researchers at the National Solar Observatory's Vacuum Tower Telescope used a new observational technique that produced special time-series images to analyze the transport of energy along the margins of hot bubbles of gas that rise as convective cells to the Sun's surface.

The enhancement of Antarctic facilities also fostered astronomy and space physics research. Wintertime astrophysical observations made by the South Pole InfraRed Explorer telescope indicated that the sky at the South Pole is much darker than at any other site previously surveyed. An additional Automatic Geophysical Observatory was deployed during FY 1995. NASA and NSF continued their joint program of long-duration ballooning in Antarctica, with payloads taking measurements to study the composition of heavy cosmic particles and the presence of high-energy gamma rays.

Upper atmospheric research supported by NSF during FY 1995 included a set of coordinated campaigns that used lidar, radar, and all-sky optical imagery to obtain signatures of "breaking" gravity waves at mesopause altitudes. A Magnetospheric Specification and Forecast Model that provides short-term forecasts of particle fluxes associated with geomagnetic activity was refined, and a campaign mounted near the magnetic equator in South America contributed critical information about the physical processes that control the onset of equatorial scintillations.

NSF also supported the April 3, 1995, launch and operation as well as a proof-of-concept GPS-Metereological (GPS-MET) experiment of the low-orbit Microlab 1 satellite, which receives signals from the constellation of GPS satellites. Initial interpretation of measurements taken by GPS-MET instruments when compared with conventional measurements indicated that temperature profiles between 5 and 40 kilometers are excellent. NSF scientists planned to make further refinements to improve the reliability of temperature measurements at other altitudes and the measurement of water vapor.

In the area of technology transfer, NSF-sponsored scientists formed a collaboration with cancer researchers to adapt astronomical computer software for use in detecting breast cancer in mammograms. Positive results from initial work on this project heightened prospects that the products of astronomical research can be adapted for other life-saving medical purposes.

Smithsonian Institution

Scientists from the Smithsonian Astronomical Observatory (SAO) made a number of important discoveries in astrophysics and space physics. SAO scientists were part of teams that used the Hubble Space Telescope to recalibrate the universe's expansion rate, and thus its age, and to analyze evolution of galaxies in the early universe. SAO scientists analyzed data from the Ultraviolet Coronal Spectrometer (UVCS) that flew aboard the Spartan 201-2 satellite and discovered a remarkably hot gas in the atmosphere above the Sun's south pole that may offer clues to the origin and nature of the solar wind.

A scientist at the Smithsonian Institution's National Air and Space Museum in Washington, DC, detected the first "natural" laser in space. Aboard NASA's Kuiper Airborne Observatory (KAO), the scientist used the aircraft's infrared telescope to observe a young, very hot, luminous star in the constellation Cygnus that emitted an intense beam of infrared light. Discovery of this naturally occurring laser has given astronomers a powerful tool for probing the conditions in circumstellar disks where astronomers believe planets form.

In the area of Earth sciences, the SAO-developed Global Ozone Monitoring Experiment was launched aboard the European Space Agency's second European Remote Sensing Satellite. It will monitor ozone levels in the Earth's atmosphere and generate a complete world ozone map every 3 days.

Finally, scientists from the SAO and Russian astronomers worked to set up the U.S. Data Center for the Spectrum-X-Gamma mission, an international collaborative space x-ray observatory led by NASA and the High Energy Division of the Institute for Space Research in Moscow.

Department of State (DoS)

DoS served as the lead agency for U.S. delegations at meetings of the INTELSAT and INMARSAT member country governments and provided relevant policy guidance to Comsat, the U.S. signatory organization. In addition, DoS played an active role in interagency discussions to develop U.S. positions on INTELSAT and INMARSAT restructuring and to promote them internationally. DoS also promoted access to overseas markets for commercial satellite companies and worked to resolve complex problems of orbit and spectrum availability.

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

During FY 1995, ACDA continued to support U.S. efforts to expand and strengthen the 28-member Missile Technology Control Regime (MTCR), which is intended to prevent the proliferation of missiles, space launch vehicles, and other unmanned aerial vehicles capable of delivering weapons of mass destruction. ACDA played a significant role in important negotiations that resulted in Russia, South Africa, and Brazil agreeing to join the MTCR. ACDA also contributed to U.S. regional missile nonproliferation efforts to freeze, roll back, and ultimately eliminate ballistic missile programs in India and Pakistan. ACDA continued to be involved in the policy process dealing with the Strategic Arms Reduction Treaty (START) and the use of U.S. and foreign excess ballistic missiles as Space Launch Vehicles (SLV's), as well as in confirming that START provisions govern SLV's that employ the first stage of an intercontinental ballistic missile or a submarine-launched ballistic missile. Finally, ACDA actively supported the efforts of the United Nations Special Commission on Iraq to destroy or remove from Iraq virtually all materials, equipment, and facilities related to missiles with a range of greater than 150 kilometers.

U.S. Information Agency (USIA)

U.S.-Russian cooperation was an important focus for USIA programs in FY 1995. Listeners throughout the world tuned into the Voice of America's live coverage of the *Atlantis* docking with the *Mir* space station in June 1995, while television stations rebroadcast Newsfile reports on the historic mission. USIA's Information Bureau produced a brochure on U.S.-Russia space cooperation for distribution at the Moscow summit in June 1995, in addition to detailed background articles on the U.S.-Russian space agreement and efforts to build the International Space Station. USIA programs also demonstrated to foreign audiences the tangible benefits of U.S. space technology, from NASA contributions to biomedical research to data about the Earth's atmosphere gathered by the Perseus project and the use of Shuttle radar to locate an ancient Cambodian city.

SPACE LAUNCH ACTIVITIES

Space Shuttle Missions

During FY 1995, NASA successfully completed seven Space Shuttle missions, the most since the record of eight in 1985. The year began with the landing of Space Transportation System (STS)-68, which was launched at the end of FY 1994. This mission was followed by, in order of flight, STS-66, STS-63, STS-67, STS-71, STS-70, and STS-69.

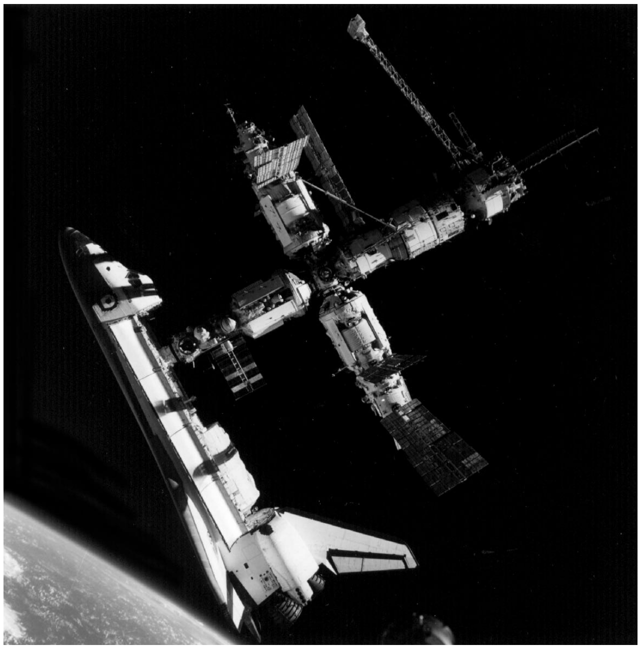
The launch of STS-68 on the orbiter *Endeavour* occurred on September 30, 1994, and it was on orbit at the beginning of FY 1995. Its primary payload was the Space Radar Laboratory-2 (SRL-2). Scientists used images produced by the radar's instruments to detect seasonal and human-made changes that occurred in the 6 months since SRL-1 flew on another Space Shuttle mission. In addition, scientists used SRL to study the surface beneath the Sahara Desert sands to confirm the existence of ancient riverbeds and to produce three-dimensional terrain maps through a technique that experts hope to refine in creating an early warning system for earthquakes and volcanic eruptions. Another element of the SRL payload was the Measurement of Air Pollution from Satellite experiment. This instrument compared the distribution of carbon monoxide in the Earth's lower atmosphere against the data taken on three previous flights. After a highly successful 11-day mission, STS-68 landed at Edwards Air Force Base (EAFB) on October 11, 1994.

The first complete mission of FY 1995 began on November 3, 1994, with the launch of STS-66 (*Atlantis*). The flight carried the third Atmospheric Laboratory for Applications and Science (ATLAS-3) along with the German Space Agency-provided Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere–Shuttle Pallet Satellite (CRISTA-SPAS-1) and the Shuttle Solar Backscatter Ultraviolet (SSBUV) payload. The objective of this set of scientific instruments was to collect temperature and trace element data for the Earth's middle atmosphere and data that measure the energy input from the Sun into the Earth system. After successfully completing all payload operations, STS-66 landed at EAFB on November 14, 1994.

STS-63, launched on February 3, 1995, had special significance as a precursor and dress rehearsal for the series of missions to rendezvous and dock with the Russian space station *Mir* planned for FY 1995–1997. It validated the flight operations techniques involved in the rendezvous, with *Discovery* approaching within 40 feet of *Mir*, then backing off to about 400 feet and performing a flyaround. Equally important, it exercised and demonstrated the coordination of the mission control teams at Houston and Moscow. The 6-person crew included the second Russian cosmonaut to fly on the Space Shuttle. After completion of the *Mir* activities, the Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN) free-flying spacecraft was deployed to make astronomical observations in the far ultraviolet spectrum. The mission also included the third operation of the commercially developed Spacehab module, with its array of technological, biological, and other scientific experiments performed for university, industry, and Government organizations across the Nation. Two of the flight crew performed a spacewalk to test spacesuit modifications and demonstrate large-object handling techniques in preparation for the upcoming assembly of the International Space Station. STS-63 landed at the Kennedy Space Center (KSC) on February 11, 1995, to complete its 8-day mission.

On March 2, 1995, the launch of STS-67 (*Endeavour*) began the second flight of the Astro payload. Astro's objective was to obtain scientific data on astronomical objects in the ultraviolet region of the spectrum. Three telescopes, taking observations in complementary regions of the spectrum, gathered data that will add to scientists' understanding of the universe's history and the origins of stars. During the mission, one telescope performed flawlessly, and the performance of the rest of the observatory exceeded prelaunch expectations. As a result, all of Astro's mission objectives were met. After setting a new mission duration record of 16.6 days, STS-66 landed at EAFB on March 19, 1995.

STS-71 lifted off from KSC on June 27, 1995, to begin the series of flights to dock with the Russian space station *Mir*. The docking itself took place on June 29, with *Atlantis* remaining docked for 5 days. The 7-person crew included two Russian cosmonauts who remained onboard *Mir* after *Atlantis* returned to Earth. Two other cosmonauts and the American astronaut who had flown to *Mir* aboard the Russian Soyuz spacecraft on March 15, 1995, returned to Earth in *Atlantis*, making it the second eight-person Shuttle crew. While docked, the crew conducted a series of biomedical measurements in support of experiments begun months before on *Mir*, in such areas as cardiovascular and pulmonary systems, neurosensory research, hygiene, and sanitation. The mission demonstrated the very successful operation of the Russian-designed docking system, which was based on the concepts used in the Apollo-Soyuz test program flown in 1975. The crew also delivered water and other supplies to *Mir* and brought back to Earth equipment no longer needed. *Atlantis* landed at KSC on July 7, 1995, to complete its 10-day mission.



A view of the Shuttle Atlantis *docked to the Kristall module of the Russian* Mir *space station. Nikolai Budarin, a* Mir *19 cosmonaut, took this photo on July 4, 1995, from a Soyuz spacecraft shortly before completion of the first docking mission between* Atlantis *and* Mir *during mission STS-71.* Atlantis *docked to* Mir *on June 29, 1995, and undocked on uly 4, 1995.*

Liftoff for STS-70 (*Discovery*) occurred on July 13, 1995. The primary objective of this flight was to deploy the NASA Tracking and Data Relay Satellite (TDRS-G). The deployment of this satellite in a geosynchronous orbit marked the completion of NASA's TDRS system. This system provides communication, tracking, telemetry, data acquisition, and command services that are essential to Shuttle and other low orbital spacecraft missions. The STS-70 crew also performed a number of important middeck experiments, including the Physiological and Anatomical Rodent Experiment sponsored by the National Institutes of Health (NIH). This experiment looked at the effects of space flight on the behavior, circadian rhythms, and development of muscle, nerve, and bone in rats. The research should contribute to a better understanding of basic physiological processes and could provide insight into a range of medical challenges on Earth. Other onboard experiments included the growth of protein crystals for use in pharmaceutical research and the investigation of a new technique for encapsulating a drug in a biodegradable polymer that allows for the controlled time release of the drug. The STS-70 mission also marked the first flight of the new Block I Space Shuttle main engine. This engine features improvements that increase the stability and safety of the Shuttle's main engines. STS-70 landed at KSC on July 22, 1995.

STS-69 was launched on September 7, 1995, carrying a 5-member crew. The mission included deployment of the Wake Shield Facility which, flying separately from the Shuttle *Endeavour*, produced an "ultra vacuum" in its wake, allowed experimentation in the production of advanced, thin film semiconductor materials. The SPARTAN spacecraft also was deployed and later retrieved with two instruments for investigations of the Sun's corona—an ultraviolet spectrograph and a white light imaging coronagraph. Scientists planned to compare SPARTAN data with data from the Ulysses spacecraft (launched in October 1990), which is observing the Sun from high above its north pole. Another SPARTAN instrument measured the extreme ultraviolet solar flux, while another made far ultraviolet observations of a torus around Jupiter associated with its moon Io. Toward the end of the mission, another spacewalk confirmed improvements in the thermal performance of the spacesuits and added to the knowledge base needed for assembling the International Space Station. The 11-day mission ended with *Endeavour* landing at KSC on September 18, 1995.

Expendable Launches

NASA launched three spacecraft on ELV's and supported one Space Shuttle launch with an Inertial Upper Stage (IUS) during FY 1995. On November 1, 1994, a Delta II launched the Wind spacecraft, one in a series of spacecraft in the International Solar-Terrestrial Physics (ISTP) Program. This spacecraft was placed in an orbit where the gravitational fields of the Sun and Earth cancel each other out, enabling the spacecraft to measure the solar wind. On December 30, 1994, NASA launched the NOAA-J spacecraft on an Atlas E into a polar orbit, where it will provide visual infrared images and vertical temperature and moisture profiles. On May 23, 1995, NASA launched another weather satellite, NOAA's GOES-J (Geostationary Operational Environmental Satellite), on an Atlas I into a geostationary orbit, where it also will provide visible and infrared imaging and sounding capabilities. Finally, the NASA team provided an IUS to support the upper-stage trajectory requirements for the TDRS-G launch on July 13, 1995.

While FY 1995 included only a few NASA ELV launches, the NASA launch vehicle team also worked to prepare for FY 1996, in which nine launches are scheduled. During FY 1995, the team supported the Pegasus XL failure recovery and investigations and the Med-Lite (Taurus, Delta-Lite, and Delta II launch vehicles) contract negotiations with McDonnell Douglas.

DoD conducted several ELV launches during FY 1995. On December 22, 1994, a Titan IV successfully lifted Defense Support Program satellite flight #17 into a geosynchronous orbit (this was incorrectly reported as a May 3rd launch in the FY 1994 report). Two Air Force Titan IV's also delivered classified DoD payloads into their assigned orbits on May 14 and July 10, 1995. On March 24, 1995, the last Atlas E booster in the Air Force inventory successfully lifted a Defense Meteorological Satellite Program satellite into orbit to replenish the DoD meteorological constellation. After this launch, DoD closed the Atlas E launch complex to reduce infrastructure costs. An Atlas IIA launched a Defense Satellite Communications System, block three (DSCS-III) satellite into orbit on July 31, 1995. On June 22, 1995, an Air Force Pegasus air-launched space vehicle carrying the Air Force Space Test Experiments Platform III (STEP-III) was destroyed when the vehicle veered from its planned flight path and began to break up.

In addition to Government launches, there were 12 commercial launches carried out from Government facilities and licensed and monitored by OCST (see table). The Air Force provided launch base and range support for these 12 commercial and civil ELV launches. This is a record number of commercial launches in 1 year and is more than double the launches carried out in FY 1994. These brought the total number of commercial launches conducted by U.S. industry to 52.

Commercial Launches in FY 1995

Company	Launch Vehicle	Payload	Date
Martin Marietta	Atlas IIAS	Intelsat 703	10/6/94
Martin Marietta	Atlas IIA	Orion	11/29/94
EER Systems	Black Brant	Experimental	12/8/94
Martin Marietta	Atlas IIAS	Intelsat 704	1/10/95
Martin Marietta	Atlas II	EHF-F4	1/28/95
Lockheed Martin	Atlas IIAS	Intelsat 705	3/22/95
Orbital Sciences	Pegasus	Orbcomm 1&2	4/3/95
Lockheed Martin	Atlas IIA	MSAT	4/7/95
Lockheed Martin	Atlas II	EHF-F5	5/31/95
McDonnell Douglas	Delta II	Koreasat	8/5/95
Lockheed Martin	LLV-1	Gemstar	8/15/95
Lockheed Martin	Atlas IIA	JCSat	8/28/95

SPACE SCIENCE

Astronomy and Space Physics

During this first complete operational year of NASA's refurbished Hubble Space Telescope (HST), astronomers made many dramatic discoveries stretching to the edge of the universe from neighboring planets in our solar system. (HST was launched in April 1990 and serviced in December 1993.) HST continues to be one of the most widely used observatories in history, as at least 60 percent of all astronomers in the United States are HST investigators who work through the Space Telescope Science Institute to accomplish their observations.

A team that included scientists from the Smithsonian Astrophysical Observatory (SAO) and other institutions used HST to derive a new, higher value for the universe's expansion rate, thus implying an unexpectedly young age for the universe. By accurately determining the distance to a galaxy in the Virgo cluster and calculating for the local effects of the universe's expansion rate, scientists were able to make this precise measurement. Astronomers determined that the universe is smaller and younger than previously thought, about 10 billion years old—only twice the age of the planet Earth.

Another team used HST to gather evidence that the clouds of hydrogen gas found between galaxies at distances of billions of light-years from Earth are at least 1 million light-years in diameter, or about 10 times larger than previously thought, and may have a remarkable sheet-like structure. These results shed new light on the properties of hydrogen gas clouds, whose nature has been a mystery since their discovery a quarter of a century ago, and may provide clues to understanding the evolution of galaxies in the early universe.

HST observations by SAO astronomers of faint stars deep inside a globular cluster provided strong evidence for the existence of cataclysmic variables. These are violently interacting double-star systems that may hold clues to the evolution of the clusters, which contain some of the oldest stars in the universe.

HST images of the most distant galaxies yet seen also showed how the structure of galaxies evolved over most of the history of the universe. Dramatically detailed images of energetic stars in our own galaxy showed the process whereby material is ejected from new stars in one direction while disks of dust, similar in size to our solar system, accumulate around the star. Scientists from the National Institute of Standards and Technology (NIST) calibrated benchmark oscillator strengths for a number of atoms calculated from the state-of-the-art atomic structure theory; this helped NASA judge the reliability of atomic data against the high accuracy of observed data such as that from HST.

In other astronomical news, the Astro-2 observatory achieved exceptional results with three telescopes observing ultraviolet light in a record-setting 16-day flight on the Space Shuttle *Endeavour* in March 1995. The most important result was a definitive measurement of the amount of helium spread throughout intergalactic space, measured to be the amount predicted by the Big Bang hypothesis. This states that the element helium was created during a hot phase of the primordial universe, only a few minutes after the Big Bang itself. The Astro-2 mission was also the first Shuttle mission with live Internet access, with more than 2 million requests logged in for mission information.

The Compton Gamma Ray Observatory (CGRO), launched in April 1991, continued a variety of observations of gamma rays, the most energetic form of light. By the end of FY 1995, scientists had recorded more than 1,400 of the mysterious gamma ray bursts, spread evenly over the entire sky. CGRO gives astrophysicists their only tool for continuing observations of this most dramatic celestial mystery. Scientists do not know whether these gamma ray explosions, lasting a few seconds, come from mysterious objects surrounding our own galaxy or whether they arise in other galaxies near the outer edges of the universe. A public debate by astrophysicists did not resolve the question. CGRO also completed a new survey of the highest energy gamma ray sources, demonstrating that about half of them are quasars with beams of energy pointed directly toward us but leaving the other half as yet unidentified.

Following CGRO and HST, the next Great Observatory will be the Advanced X-Ray Astrophysics Facility (AXAF). Figuring and polishing of the eight x-ray reflecting *mir*rors for AXAF were completed during FY 1995, in preparation for *mir*ror coating. These are by far the most precise optics ever developed for imaging x-rays, and the completed mirrors significantly exceed performance requirements. In addition, the high-resolution camera being constructed at the SAO passed its critical design review.

The Ulysses spacecraft, launched in October 1990, successfully completed its passage over the northern pole of the Sun, completing the first ever exploration of the solar wind above its polar regions. Ulysses is now moving away from the Sun and will return again to pass over the Sun's poles in the years 2000 and 2001. The polar passages occurred during solar minimum, when activity on the Sun is at its lowest and when the polar regions are dominated by high-speed solar wind flows. Ulysses found that the solar wind was dominated by high-speed flow for latitudes above about 30 degrees north or south. Scientists working on the Ulysses and Voyager spacecraft projects detected oscillations in solar wind measurements, providing clues about the deep interior of the Sun. SPARTAN 201, a small satellite deployed and retrieved by the Space Shuttle in September 1994 and September 1995 during the polar passages by Ulysses, discovered the presence of unexpectedly hot (about 10 million degrees Centigrade) gas above the Sun's poles. This may explain why the solar wind speed is so high (500 miles per second) in the solar polar regions.

Voyagers 1 and 2, launched in 1977, and Pioneers 10 and 11, launched in 1972 and 1973, respectively, continued their exploration of the outer frontiers of the solar system. Now nearly twice as far from the Sun as Pluto, these spacecraft are approaching the boundary between the solar system and interstellar space. The Voyagers, which have sufficient power reserves to operate until 2015, could reach that boundary by the end of this century and become the first interstellar probes.

NASA was also active in several international programs devoted to space physics research. Yohkoh, a joint Japanese/U.S. mission launched in August 1991, continued its measurements of the solar corona and observation of the change in its x-ray brightness, activity, and structural complexity as it evolves from solar maximum to solar minimum. In November 1994, the Global Geospace Science (GGS) Wind spacecraft was launched successfully into a path upstream of the Earth's magnetosphere, where it has been providing information on the solar wind that determines conditions in the magnetosphere, including the downstream tail region. The Geotail spacecraft discovered particles from the Earth's ionosphere in the distant magnetic tail region at distances (210 Earth radii) beyond that of the Moon. Yohkoh, Wind, and Geotail are key elements of the International Solar-Terrestrial Physics (ISTP) Program for studying solar variability and its effects on the near-Earth space environment. This program involves spacecraft from the United States, Japan, Europe, and Russia. Several other ISTP spacecraft were scheduled to be launched by 1996.

In the suborbital area, NASA scientists made new discoveries about upper atmospheric flashes during aircraft and ground campaigns. These flashes, called sprites (red flashes) and jets (blue fountains), appear over intense thunderstorms and extend as high as 60 miles into the ionosphere. Scientists obtained the first spectra of a sprite in summer 1995 and also obtained high-resolution images showing a new type of sprite and its complex structuring. Another flight campaign over intense thunderstorms in Central America detected far fewer events than were seen over similarly intense storms over the Great Plains last year. Scientists believe that the study of these dramatic upper atmospheric flashes, and the thunderstorms with which they are associated, can lead to increases in airplane safety. In another element of the suborbital program, NASA's sounding rocket program had 30 consecutive launch successes in FY 1995.

NASA's Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) spacecraft continued its study of the energetic electrons and atomic ions from the Sun, as well as interplanetary, interstellar, and magnetospheric space. SAMPEX data are providing critical insights into how cosmic rays are accelerated out at the heliospheric shock, caused by the collision of the solar wind with the interstellar gas. SAMPEX measurements have provided data on energetic particles in the trapped radiation belts, which can affect electronic systems in spacecraft such as communication satellites.

Using the Very Long Baseline Array (VLBA) of the National Science Foundation (NSF), a team of scientists from the SAO and Japan were able to show compelling evidence for the existence of a black hole in the center of the galaxy NGC 4258. The latest telescope of the NSF-sponsored National Radio Astronomy Observatory, the VLBA's 10 antennas simulate the magnifying power of a radio telescope more than 5,000 miles in diameter. Astronomers from Japan's National Astronomical Observatory and the Harvard-Smithsonian Center for Astrophysics pointed the VLBA to the center of NGC 4258 to make images of such high resolution that the individual positions of water vapor masers could be measured as well as the speed of their motion along the line of sight to the galaxy. This is equivalent to reading a sign on a truck in Los Angeles from New York and measuring the speed of the truck as well. A simple calculation yielded the mass of the central object, 30 million solar masses, much too large a mass to be contained in the available volume except by a black hole. The massive black hole in the center of NGC 4258 has presumably grown to its huge size through years of accretion of matter in the densely populated region of the galaxy's center.

Astronomers at the NSF-sponsored Kitt Peak National Observatory investigated the formation of the Milky Way galaxy's Galactic Halo, an enigmatic distribution of older stars that appears key to understanding the formation of our galaxy. The challenge in studying the Halo came in isolating a sample of stars guaranteed to be members of that population. The team of astronomers was surprised to observe that the flattened population of "young" stars seems to be older than the spherical population of "old" stars. Was this subsystem of galactic stars formed during the collapse of the proto-galaxy from an initial spherical distribution of gas, or was it formed by the aggregation of smaller dwarf galaxies trapped in the gravitational field of the larger Milky Way? One explanation is that both scenarios for formation of the Milky Way contributed, with the flatter distribution of stars coming from the collapse phase of the proto-galaxy and the younger spherical population resulting from the capture and shredding of neighboring dwarf galaxies. This challenging topic remained the focus of intense observational effort.

Scientists used the NSF-sponsored Cerro-Tololo Inter-American Observatory's Blanco Telescope to observe and analyze the Magellanic Stream, a large filament of neutral hydrogen gas from the Milky Way's radio emission that originates at the Small Magellanic Cloud (a Milky Way satellite dwarf galaxy) and extends almost one-third of the way around the sky. The astronomical team discovered unexpectedly strong optical line emission from hydrogen at the leading edge of the stream, where the density of neutral hydrogen detected in radio increases steeply. What is the source of this energetic emission? The association with the cloud's leading edges suggests that as the stream moves through high-pressure, low-density gas, shock waves propagating into the gas of the stream produce this emission. While radio, optical, and x-ray observations have long shown that there is diffuse gas associated with the Milky Way up to 150,000 light-years away from our galaxy, the origin and distribution of this hot gas remained controversial.

Astronomers at the NSF-sponsored vacuum tower telescope on Sacramento Peak used a new technique called phase-diverse speckle imaging to take time-series images of hot gaseous bubbles rising to the surface of the Sun. The resulting time series of a magnetic region without sunspots showed the highly dynamic visible layer of the solar atmosphere at scales of less than 200 kilometers. This new imaging technique depicted the detailed evolution of the bright edges of granules (the convective cells on the solar surface) for the first time. Scientists hoped that further study of these granules will yield useful information about the hot gaseous layers of chromosphere and corona above the Sun's surface.

The Center for Astrophysical Research in Antarctica (CARA), one of NSF's 25 Science and Technology Centers, completed its second year of year-round operations. The cold dry atmosphere and lack of diurnal variation make the South Pole the best site on Earth for many radio and infrared measurements. Site measurements by the South Pole InfraRed Explorer telescope have now indicated that the sky at the South Pole is darker by a factor of at least 20 than any other site previously surveyed. PYTHON, one of two telescopes comprising the Cosmic Background Radiation Anisotrophy, made measurements at the South Pole during the past two austral summers and operated for the first time during the winter. PYTHON confirmed the Cosmic

Microwave Background (CMB) anisotropy, first measured by the Cosmic Background Explorer (COBE) satellite, and began to make a finer scale map of the CMB than COBE could. The 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory, built by the SAO, was installed at the South Pole during the austral summer of 1994–1995. It quickly produced more than 10,000 spectra of neutral carbon lines in the galaxy and the Large Magellanic Cloud and also made measurements of atmospheric trace gases, such as ozone and carbon monoxide. Australian and NASA investigators working with CARA have undertaken a survey of the South Pole atmospheric transparency in the mid-infrared (5 to 40 millimeters). Measurements made during the 1994–1995 summer were encouraging enough for Goddard Space Flight Center (GSFC) scientists to propose that monitoring equipment be wintered during 1996.

During the austral summer of 1994–1995 in Antarctica, NSF deployed a new Automatic Geophysical Observatory (AGO), bringing to four the number now operating in the field. The AGO's, which were built by Lockheed, provide heat, power, and data storage for a suite of several remote-sensing instruments for years of unattended operation. When all the AGO's are deployed, they will provide, in conjunction with a few manned stations, uninterrupted and overlapping observations of the very high magnetic latitude ionosphere with a number of instruments. Following the lead of NSF, the British and Japanese Antarctic programs began developing their own AGO's, which will provide additional data in the lower latitude auroral zone. The AGO network will complement significantly the ISTP Program, especially the NASA Polar satellite.

Also during the austral summer of 1994–1995, NASA and NSF continued their joint program of long-duration ballooning in Antarctica. NASA launched two joint payloads during FY 1995—one carried emulsion track chambers to study the composition of heavy cosmic ray particles, and the second payload was a very large, high-energy gamma ray detector. Both payloads were recovered after flights of more than 10 days.

A scientist at the Laboratory for Astrophysics at the National Air and Space Museum (part of the Smithsonian Institution) in Washington, DC detected the first "natural" laser in space. Aboard NASA's Kuiper Airborne Observatory (KAO), the scientist used the aircraft's infrared telescope to observe a young, very hot, luminous star in the constellation Cygnus. Such lasers are created as intense ultraviolet light from the star "pumps," or excites, densely packed hydrogen atoms in the gaseous, dusty disk surrounding a young star, causing the atoms to emit an intense beam of infrared light. The discovery of this naturally occurring laser has given astronomers a powerful tool for probing the conditions in circumstellar disks where planets are thought to form.

Solar System Exploration

In October 1994, Swiss astronomers Michel Mayor and Didier Queloz reported their discovery of a large planet (about half the mass of Jupiter) orbiting the star 51 Pegasi. American astronomers Geoffrey Marcy and Paul Butler of San Francisco State University verified the discovery. The only previous evidence of planets orbiting another star was the unexpected discovery of at least two planets in orbit around a pulsar, the remnant of a supernova. 51 Pegasi is a normal star, somewhat older than our Sun, but the new planet is dramatically different from anything found in our own solar system. Despite its massive size, this planet orbits so close (about 5 million miles) that it is within the hot, tenuous outer atmosphere (the corona) of its star and completes a revolution in about 4 days. By contrast, Jupiter orbits the Sun at a distance of nearly 500 million miles and completes a revolution in about 12 years.

Scientists recently gained a new understanding of the asteroid impact that occurred 65 million years ago in modern-day Yucatan, Mexico, that led to the extinction of the dinosaurs. Scientists had thought that the global dust cloud raised by the impact blotted out enough sunlight to disrupt photosynthesis in plants for 3 to 6 months. It was not clear that this was enough time to cause mass extinctions. A new study, by Kevin Pope of Geo Eco Arc Research, Inc., and colleagues at NASA's JPL and the Institute for Dynamics of Geospheres, Russian Academy of Science, revealed that the region where the asteroid struck has thick geological deposits of sulfur-containing minerals. The asteroid impact could have vaporized these mineral deposits and released an enormous quantity of sulfur, which rapidly became transformed into thick clouds of sulfuric acid. These clouds might have extended the photosynthesis blackout period slightly, but more importantly it led to an "impact winter" of freezing or near-freezing temperatures that lasted until the acid gradually rained out of the atmosphere in about 10 years. Land species that survived this long winter might have lived near seacoasts—in climatic "refuges" with temperatures moderated by the enormous heat capacity of the oceans.

Training its new and improved optics on objects in our solar system, HST discovered a distant swarm of comets called the Kuiper Belt that was long thought to exist in the outer reaches of the solar system. HST obtained images of the newly discovered Comet Hale-Bopp, showing that the solid part of this comet is much larger than Halley's Comet, giving rise to predictions that Hale-Bopp may be the "comet of the century," when it passes closest to Earth in early 1997.

HST images and spectra also revealed unexpected weather changes on Neptune, Mars, and Venus. There are unexpectedly rapid cloud changes on Neptune. The atmosphere of Mars is much clearer and colder than 20 years ago. Venus has less sulfur dioxide, implying less volcanic activity, than in the 1970s.

Studies of presolar silicon carbide and aluminum oxide grains found in primitive meteorites have led to definitive new insights into the evolution of stars. These grains were formed of material ejected from stars born millions or billions of years before the Sun. They were gently incorporated into asteroid-sized bodies during the birth of the solar system and preserved unchanged until the present time. Scientists used the chemical and isotopic compositions of these presolar grains to infer physical properties of the stars, such as temperatures, atmospheric densities, and the degree of mixing between inner and outer layers. The preservation of the grains has also shed new light on the physical conditions in the primitive solar nebula. The gas and dust in the nebula are known to have been much cooler, on average, and much less homogeneous; otherwise, the presolar grains would not have survived.

New theoretical studies by a scientist at the Lunar and Planetary Institute in Houston have suggested that Pluto's highly eccentric and inclined orbit is a natural consequence of the formation and early evolution of the solar system, rather than the result of a violent event. Pluto likely began in nearly circular orbit with low inclination, but interactions between giant planets and residual planetesimals during the late stages of planet formation caused Pluto to be captured in orbital resonance with Neptune. The resulting gravitational perturbations by Neptune distorted Pluto's orbit. A further consequence of these results is that most of the remaining planetesimals beyond Neptune, the so-called Kuiper Belt Objects, are trapped in narrow zones at the locations of orbital resonances with Neptune. These objects are probably the source of short-period comets that penetrate into the inner solar system.

Scientists from USGS, a bureau within DoI, assisted with final preparations for NASA's Galileo mission, which reached Jupiter on December 7, 1995. USGS staff developed the software system that will be used to analyze Near-Infrared Mapping Spectrometer (NIMS) data. In August 1995, Galileo plowed through the most intense interplanetary dust storm ever measured, and scientists hope to identify the source of this dust phenomenon after further analysis of data.

To support mission planning and data analysis for NASA's upcoming Mars Global Surveyor mission, which is to orbit the planet for one Martian year, USGS completed a revised 1:5,000,000-scale Mars map series of 30 quadrangles and a series of global digital color image models of Mars. On the upcoming Mars Pathfinder mission to explore the Martian surface, USGS specialists in planetary photogrammetry made several large digital image mosaics and extracted digital terrain models of the Mars landing site for use in validating the primary site in Chryse Planitia. On the future Cassini mission to Saturn, USGS made major contributions to planning the observational sequences and helped define software requirements for the uplink and downlink mission operations phase.

The approach of asteroid 1991 JX to 0.034 astronomical units from Earth (its closest position for at least the next two centuries) on June 9, 1995, provided an excellent opportunity for a variety of NASA-sponsored radar investigations. These included the first intercontinental radar astronomy observations, with transmission from the Goldstone Deep Space Net 70-meter antenna in California to reception in Ukraine and Japan. The 1991 JX asteroid is no more than 0.6 kilometers large, making it the smallest solar system object imaged thus far.

Microgravity and Life Sciences

With the launch of U.S. astronaut Norm Thagard to the Russian space station *Mir* aboard a Russian spacecraft in March 1995, U.S. and international space research began a new era of expanded opportunities for microgravity research and technology development on orbit. Thagard's mission to *Mir* included a number of firsts for human space flight—a record total of 10 humans were together on orbit in the docked Shuttle/*Mir* spacecraft for the first time—and when

Thagard and his two Russian colleagues returned to Earth aboard the Space Shuttle *Atlantis*, they were the first humans to ride to orbit in a vehicle from one nation and return in that of another. During his record-breaking 116-day mission on *Mir*, Dr. Thagard and the two cosmonaut crew members conducted a wide range of research using both U.S. and Russian research hardware. They conducted and participated in studies on the challenges of long-duration space flight for human physiology, behavior and performance, and advanced life support. They worked to characterize the air and microgravity environment aboard *Mir* and to gain insights into the research environment that will be provided by the International Space Station. NASA also worked with its Russian counterparts to standardize U.S. and Russian radiation-detection data.

In addition, the 1995 *Mir* flights allowed the longest ever period of protein crystal growth in space, with the placement of samples on *Mir* in June 1995 and their retrieval from *Mir* in November 1995. In FY 1995, NASA also outfitted the Russian Spektr and Priroda laboratory modules with more than 2,000 kilograms of research equipment. The Russian Space Agency launched Spektr on May 20, 1995, and successfully docked it to *Mir*. Scientists expect that insights gained aboard *Mir* will affect the development of technology and research programs for the International Space Station and future long-duration missions.

In addition to the investigations conducted during missions to the *Mir* space station, NASA used middeck lockers aboard other Space Shuttle missions to conduct life and microgravity sciences experiments. NASA used the Space Shuttle to fly a series of collaborative experiments with the NIH to explore issues in developmental biology, basic physiology, and bone loss and growth. Other middeck experiments included cell biology, immune cell function, inorganic crystal growth, and biotechnology investigations.

In a preliminary test of NASA's bioreactor (an advanced tissue-culturing apparatus) for the ISS, colon cancer tumor cultures taken to orbit grew to be approximately twice the size of ground controls. While the significance of these experimental results is still being evaluated, the technical performance of the experiment was excellent.

Two sounding rocket tests of the Spread Across Liquids experiment were successfully conducted at White Sands Missile Range on November 22, 1994, and August 28, 1995. The experiments are investigations of flame spread characteristics across a deep pool of combustible liquid in a microgravity environment. These experiments are important both for fire safety on orbit and as fundamental research on the nature of combustion. Materials scientists at NIST also conducted research on the optical properties of selected substances at high temperatures and the nature of combustion and flame spread in a microgravity environment.

A newly outfitted DC-9 microgravity research aircraft began operations in July 1995. The new DC-9 serves as a low-gravity research facility that is capable of producing brief periods of low gravity by flying special parabolic flight paths. The plane plays a vital role as a test platform for preparing microgravity experiments for flight on both the International Space Station and the Space Shuttle.

More Shuttle protein crystal growth experiments were flown in FY 1995 than the total for the previous decade. Protein crystals grown on orbit supported drug development efforts by major pharmaceutical firms seeking improved treatments for a variety of medical problems, including diabetes and emphysema.

Experiments from the Rensselaer Polytechnic Institute aboard the Space Shuttle produced important new insights into a process by which the structure of metal forms. The results of these investigations provided insights into the solidification process, which could not be made precisely on Earth. Results of this experiment may aid in the development of stronger or more corrosion-resistant metal alloys.

In FY 1995, NASA and NIH managers completed the selection of 32 principal investigators for Neurolab, the next dedicated life sciences Shuttle mission. Scheduled to fly during FY 1998, the Neurolab mission will concentrate on neuroscience and will support a mix of prominent domestic and international investigators.

Also during the fiscal year, NASA scientists completed preparations for the launch of the second U.S. Microgravity Laboratory (USML-2), a major Spacelab mission dedicated to microgravity research. While the launch of the mission was delayed until October 1995, scientists completed all experimental preparation and integration in FY 1995. Researchers prepared many investigations on crystal growth and surface-tension-driven convection. Building on scientific foundations laid by previous Space Shuttle missions, USML-2 investigators pursued new insights into theoretical models of fluid physics, combustion science, materials science, and biotechnology.

NASA completed Phase I of the Early Human Test Initiative, a 15-day experiment to evaluate the use of higher plants for air revitalization in extraterrestrial habitats. A life sciences researcher entered the closed test chamber on July 24, 1995. The chamber contained facilities to maintain him for the test period without any additional supplies and a plant growth facility containing a mature wheat crop. The wheat crop produced sufficient oxygen and removed carbon dioxide to meet the requirements of 1.6-person equivalents. After 6 days of operation, the plant photosynthesis was matched to the metabolic requirements of the test subject by adjusting the lamps for the plants. The experiment was successfully concluded when the researcher exited the test chamber on August 8, 1995.

SPACE FLIGHT AND SPACE TECHNOLOGY

Space Shuttle Technology

The Space Shuttle's primary purpose in FY 1995 continued to be transporting people and cargo safely into low-Earth orbit. At the end of the year, NASA had four active orbiters in its fleet—*Atlantis*, *Columbia*, *Discovery*, and *Endeavour*. During FY 1995, *Columbia* completed its orbiter maintenance down period in the Palmdale, California, facility. As the year ended, technicians were preparing *Discovery* for delivery to Palmdale for its down period. Technicians planned to modify *Discovery* so that it will be able to dock with the Russian *Mir* space station and assemble the International Space Station.

The Space Shuttle program initiated a major restructuring that will focus space flight operations under a single prime contractor, among other changes. NASA civil service personnel are to begin retreating from the routine daily operations and change their role to auditing and providing independent assessments of Shuttle problems. NASA managers are to retain sufficient technical insight into contractor activities to ensure a safe commitment to flight, in addition to managing all Shuttle hardware development and safety improvements.

NASA engineers continued redesigning the external tank to reduce structural weight and thus improve the performance of the Shuttle system. The redesign involved substituting aluminum lithium for the existing aluminum alloy to take advantage of the new material's greater strength per weight. As of the end of FY 1995, the first launch of the redesigned super lightweight tank was scheduled for late in calendar year 1997.

Space Shuttle Main Engine project managers aggressively pursued the development and implementation of safety and reliability improvements in FY 1995. In the current engine, technicians upgraded five major components in two block changes. Block I incorporates the new phase II+ powerhead, the single-coil heat exchanger, the alternate high-pressure fuel turbopump, and the large throat main combustion chamber. The Block I engine completed the certification program in May 1995 and had its first flight in July 1995. The first of four development/certification large throat main combustion chambers was delivered during FY 1995 and is to be incorporated into the first development Block II engine for testing. Engineers involved in the oxidizer turbopump development successfully resolved all of the major technical problems they encountered early in development. Due in large part to this success, Congress approved the resumption of development work on the fuel turbopump, which had been in caretaker status since 1991. Engineers and technicians began development testing of the Block II engine at the end of the fiscal year, and at that time the Block II configuration was scheduled to enter service in September 1997.

The Solid Rocket Booster successfully supported the six Shuttle flights during FY 1995. Redesigned Solid Rocket Motor nozzle production remained in Utah. NASA had wanted to move it to the former Advanced Solid Rocket Motor (ASRM) site in Mississippi, but NASA ended up closing this ASRM site and transferring control of the site to the State of Mississippi.

In the area of Space Shuttle systems integration, the Day-of-Launch I-Load Update (DOLILU) system was available on all FY 1995 missions. This system updates the flight trajectory to account for actual winds on launch day. In June 1995, software engineers successfully implemented the DOLILU II system, which also incorporates the main engine control tables, solid rocket trim data, and aerodynamic control data on launch day. This system further optimizes the ascent trajectory of the Shuttle and eliminates significant flight-to-flight trajectory design activities. Integration efforts during FY 1995 also included analyses of structural loads; resolution of in-flight anomalies, waivers, and changes; and software development and testing for the control of each mission. To support the International Space Station mission requirements, NASA began to identify, develop, and schedule Shuttle performance enhancements. Engineers developed systems integration plans to ensure the orderly implementation of these enhancements into the Space Shuttle program. These plans specified design analyses and test requirements to provide definition of flight margins. Engineers and technicians also completed on schedule several systems analyses to certify the safety of the Shuttle's performance enhancements and to ensure compatibility of design modifications to the external tank, main engines, and the orbiter. At the end of the fiscal year, Shuttle managers had specified all of the necessary enhancements to support the first Shuttle-launched International Space Station assembly flight, which is scheduled for December 1997.

Engineers at Kennedy Space Center (KSC) redesigned the launch and landing ground support equipment for the Shuttle to eliminate the use of ozone-depleting chlorofluorocarbons (CFC). Two key items are the portable purge units, which purge the Shuttle orbiter immediately after landing, and the Shuttle launch pad environmental control system, which provides clean, conditioned air to the launch vehicle elements and the payload changeout room. KSC engineers also began developing aqueous cleaning and cleaning verification methods to reduce CFC freon-113 usage and associated release to the atmosphere. KSC managers plan to eliminate totally the use of CFC freon-113 by the end of 1997.

Engineers began developing a propulsion advisory system as an advanced software tool to aid in data analysis and problem resolution during launch, landing, and dynamic testing. Propulsion system experts used this software to monitor a wide range of data to assess propulsion system health. This software includes an intelligent graphical interface and display capability that provides enhanced data representation, including saturation curve plotting. The new software system has simplified the task of performing trend analysis, system health monitoring, and diagnosis.

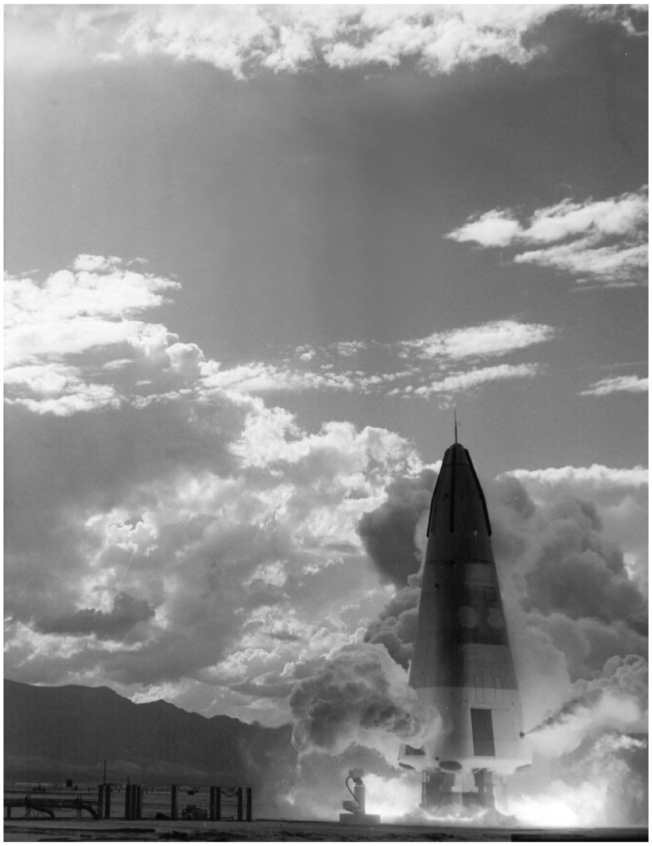
Approximately 36,000 photographs were taken of critical Space Shuttle mission closeout activities. Technicians began to digitize these photos and store them on electronic media that provide better storage, records management, and retrieval. Archivists hoped to configure a system in which users can review these photos online in their offices to increase the ease of efficiency of future closeout activities.

Reusable Launch Vehicles and Other Launch Systems

NASA initiated the RLV technology development and demonstration program in early FY 1995 in response to the National Space Transportation Policy of 1994. DoD worked with NASA on this program, bringing expertise in such areas as flight test, operations, and composite structures. NASA has structured the RLV program differently from previous similar programs, with new relationships between Government and industry, a faster program pace, and a streamlined management structure. NASA managers designed the RLV program to benefit the broad range of future space launch needs, from the emerging small payloads market to the future supply needs of the International Space Station.

In FY 1995, the Air Force's Phillips Laboratory continued the series of flight experiments begun in 1994, using the McDonnell Douglas Delta Clipper–Experimental (DC-X) launch vehicle. The DC-X was designed to test the feasibility of a vertical landing liquid oxygen and hydrogen rocket operated with the same simplicity as conventional aircraft. While the DC-X is a simplified demonstration vehicle, many of the concepts that it incorporates would be necessary for an actual cost-effective RLV. The year began with the repair of damage to the DC-X vehicle from an explosion in a ground utility trench during the previous flight test in June 1994. The vehicle, which had successfully completed a controlled emergency landing after the explosion, required repairs to the aeroshell and the liquid hydrogen tank. On May 16, 1995, the DC-X resumed test flights, traveling vertically 1,150 feet and then moving laterally until it was positioned over its landing pad located 350 feet from the flight stand. On June 12, 1995, the DC-X climbed to 5,700 feet and demonstrated for the first time the use of four gaseous oxygen-hydrogen thrusters. In the eighth and final test flight of the DC-X configuration, on July 7, 1995, the DC-X demonstrated a reentry rotation maneuver, first pointing its nose 10 degrees below the horizon and then rotating 138 degrees to land with the nose pointing up. This maneuver would be required by a full-scale vertical landing RLV. At the conclusion of the flight tests, the Air Force transferred the DC-X to NASA to be upgraded for a series of flight tests in 1996 as the DC-XA (Delta Clipper–Experimental Advanced).

NASA initiated a second element of the RLV program, the X-34, through a Cooperative Agreement Notice (CAN) with Orbital Sciences Corporation in the early part of 1995. The X-34 was to demonstrate advanced vehicle technologies in flight for a fully reusable booster that has the promise of reducing costs in the small launcher market by about 50 percent. The X-34 was to progress rapidly through hardware design and development to flight demonstrations in 1997.



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NASA also initiated the X-33 program, the third RLV flight test program, through a CAN in early 1995. As in the total RLV program, the X-33 is a NASA partnership with industry, with industry as the lead. The X-33 will demonstrate critical operations and component technologies on the ground and in flight to permit a decision at the end of the decade on the technical feasibility of single-stage-to-orbit (SSTO), as well as the viability of private financing for the next generation of launch vehicles. During FY 1995, the X-33 program was in the design phase, with three industry teams led by Lockheed Martin, McDonnell Douglas Aerospace, and Rockwell International in competition through 1996.

RLV program managers have committed themselves to developing new operations and component technologies, as well as to producing an industry-Government relationship that will revolutionize the space launch industry worldwide. If successful, the RLV program will deliver "leapfrog" technology that will permit the U.S. space launch industry to regain worldwide leadership in low-cost space launch operations. The staff of DoT's Office of Commercial Space Transportation (OCST) provided technical and analytical support, as part of the Non-Advocate Review Team for the RLV technology program, to ensure that commercial launch services requirements will be taken into account in the development of this technology.

A significant first step in modernizing America's spacelift fleet took place in August 1995 when DoD selected four prime contractors for its Evolved Expendable Launch Vehicle (EELV) Low Cost Concept Validation program. The EELV is to use existing technology to develop a family of ELV's to replace the current medium- and heavy-lift vehicles and supporting infrastructure. The goal is to reduce overall launch system costs by 25 to 30 percent by moving away from current space launch vehicles such as the Titan, Atlas, and Delta vehicles, while also maintaining or improving these current systems' operability and reliability. OCST provided technical assistance and policy analysis as a member of DoD's Source Selection Advisory Board for a review of the EELV program.

International Space Station

During FY 1995, engineers accomplished many of the 1993 Space Station redesign goals on the revamped International Space Station program. NASA personnel solidified their "core team" management philosophy with the definitization of the $5.63 billion design and development contract with the prime contractor, Boeing. The collocation of Boeing in the ISS Program Office represented a new way of doing business at NASA, yielding significant decision-making authority to the contractor.

In March 1995, the International Space Station program successfully completed the first in a series of incremental design reviews. This review was a comprehensive assessment of the design and technical feasibility for the first six American and the first five Russian International Space Station assembly flights and a forward planning review of all assembly flights. In April 1995, NASA held a major design review for the Functional Cargo Block (FGB), which certified readiness to proceed with the manufacture of this important first element of the International Space Station. The FGB will provide propulsion, guidance, and control in the early stages of the Station, and then will serve as a fuel and equipment storage facility in the later stages. Also in FY 1995, the program completed the final major design review of the solar dynamic flight demonstration for fundamentally new power technologies.

Contractors have delivered more than 70,000 pounds of International Space Station qualification and flight hardware. Fabrication of the first U.S. element (Node 1), the Structural Test Article (Node 2), and the U.S. lab module have been completed. The contractor also completed machining of the two nodes and nearly completed machining of the U.S. lab module at the end of FY 1995. Contractors delivered a wide variety of components, including the solar array mast and panels, the thermal radiator rotary joint mockup, truss segments, common berthing mechanism simulators, demultiplexers, rack structure assemblies, and hatch assemblies.

Throughout the fiscal year, development programs continued in other partner countries as well. The Canadian government, after resolving difficult budget limitations in 1994, continued its development program for the mobile servicing system, which will provide external ISS robotics. Japan has continued to remain on schedule in developing the Japanese Experiment Module, consisting of a multipurpose pressurized laboratory element, an unpressurized exposed facility, a remote manipulator (robotic) system, and experiment logistics modules. In Europe, the nine nations involved in the International Space Station program continued discussions on both the content and individual country financial contributions for the program. By the end of the fiscal year, European space and research ministers were poised to give the final approval for a European contribution consisting of a pressurized laboratory called the Columbus Orbital Facility laboratory support equipment for early use in the U.S. laboratory and the Automated Transfer Vehicle (ATV), which will be used in conjunction with the Ariane 5 launch vehicle for delivery of logistics and propellant for Station reboost. In August 1995, while already working on the FGB, Russia's Khrunichev Enterprise and the Boeing Company reached a formal agreement on a contract for the development, launch, and on-orbit checkout of the FGB.

While ISS development work continued, the Shuttle-*Mir* program (Phase I ISS) was proceeding on schedule to meet its objectives of providing operational experience, Station risk mitigation, technology demonstrations, and early science opportunities. Major milestones achieved during the year included the flight of a second Russian cosmonaut, Vladimir Titov, on the Space Shuttle in February 1995. During that mission, Russian and American space and ground crews operated jointly for the first time in more than two decades as the Shuttle approached to within 10 meters of the *Mir* space station. In March 1995, a Soyuz TM-21 vehicle was launched from Baikonur, Kazakhstan, carrying the *Mir* 18 crew, including U.S. astronaut Dr. Norman Thagard, to the *Mir* space station. Dr. Thagard's 115 days aboard *Mir* provided the first long-duration medical data on an American astronaut since the Skylab mission during the 1970's. Also in May 1995, the Russian Spektr module, carrying 750 kilograms of U.S. life sciences hardware, was launched to the *Mir* space station. In June 1995, the Space Shuttle *Atlantis* made the historic first rendezvous and docking with the *Mir*. While the vehicles were docked, the crew of *Atlantis*, consisting of five astronauts and two cosmonauts, and the *Mir* 18 crew conducted experiments similar to those planned for the International Space Station. After 5 days of docked operations, *Atlantis* departed, leaving two new cosmonauts aboard *Mir* and returning the *Mir* 18 crew to KSC.

In the area of microgravity research for the International Space Station, NASA, in consultation with prospective users in the scientific community, continued to design and prepare a series of seven major laboratory facilities and a glovebox facility. In July 1995, NASA released a Request for Proposal (RFP) for the centrifuge facility, and a selection decision was planned for the first quarter of FY 1996. NASA conducted a successful preliminary design review for the ISS furnace facility early in 1995 and made considerable progress in design/development activities. In May 1995, the Fluids and Combustion Facility entered its definition phase for multi-user hardware development for experiments in fluid physics and combustion science. Low Temperature Research Facility definition activities began in 1995.

In the commercialization arena, NASA's commercial Space Station utilization program selected four areas of effort for space processing payloads for Phase I Shuttle-*Mir* flights. These activities involve industry, university, and Government partnerships accomplished through the Centers for the Commercial Development of Space.

Energy

In FY 1995, the Department of Energy (DoE) continued its work in the fabrication of 3 General Purpose Heat Source Radioisotope Thermoelectric Generators (GPHS-RTG's) and 157 Radioisotope Heater Units (RHU's) for NASA's upcoming Cassini mission to Saturn. RTG's directly convert the heat from the decay of the radioisotope Plutonium-238 (Pu-238) into electricity without any moving parts; they have been employed successfully on more than 20 spacecraft of long-duration missions. Technicians completed all of the Pu-238 processing required for the RTG's and RHU's and completed fabrication of the first RTG's heat source during FY 1995. The prime system contractor completed the production of all thermoelectric elements and assembled and acceptance-tested the first thermoelectric converter. Finally, DoE supported NASA in developing environmental documentation and performing safety testing for the safety analysis reports required for the launch approval process of Cassini.

In addition, DoE took delivery in 1995 of 4.2 kilograms (for a total of 9.2 kilograms) of Russian-produced Pu-238 to supplement the existing U.S. inventory of Pu-238. This Pu-238 is to fuel the power sources for future planetary exploration spacecraft. This is the first foreign-produced material capable of being pressed directly into pellets to fuel RTG's.

DoE and NASA officials signed a Supplemental Agreement to the basic Memorandum of Understanding on radioisotope power systems for the Mars Pathfinder mission. DoE is to provide three Lightweight Radioisotope Heater Units (LWRHU's) from its inventory (these are actually spares from the Galileo and Ulysses missions) for this upcoming launch. DoE also began preparing a Final Safety Analysis Report on the LWRHU's for the Mars Pathfinder mission.

For NASA's Pluto Express mission, DoE engineers and scientists studied advanced converter technologies to provide high-efficiency and lightweight power sources. DoE engineers also initiated technology development work to investigate and demonstrate the viability of advanced power converters using thermophotovoltaic, alkaline metal, and Stirling engine technologies.

In conjunction with JPL, DoE has been exploring the use of a bimodal (power/propulsion) space reactor system to support NASA's New Millennium spacecraft program. In a joint program with the Air Force, DoE developed design concepts for three bimodal space reactor power systems.

DoE staff also participated in an interagency technical working group on space reactor systems sponsored by the Defense Nuclear Agency to review its Topaz International Program. This program is centered on a thermionic space power system developed in the former Soviet Union, called the Topaz II. Unlike RTG's, the Topaz reactor has moving parts like a ground nuclear powerplant. At the component level, under the DoE-managed 40-kilowatt (of electric power) thermionic space reactor program, technicians completed the initial evaluation of a single-cell thermionic fuel element that is to double the power of past designs. At the basic research level, work continued on the cesium effects on bulk and surface conductivity of seal insulators and collector sheath insulators and the cesium plasma erosion of inter-electrode gap ceramic spacers.

Safety and Mission Assurance

NASA continued to emphasize a strong contributing safety, reliability, and quality assurance (SR&QA) presence within current and future flight projects. In FY 1995, seven Space Shuttle missions, including the historic Space Shuttle/*Mir* rendezvous and docking missions, were completed safely and successfully. NASA initiated new quality management support activities and integrated SR&QA expertise into its aeronautics, microgravity programs, Mission to Planet Earth (MTPE), access to space and space processing activities, and space science programs. NASA SR&QA experts supported critical design reviews, program design reviews, independent assessments, and technical reviews for safety and mission assurance and guided the development of quality plans for new aeronautics programs.

The International Space Station independent assessment activity resulted in technical and management improvements in such areas as end-of-life disposal, microgravity reliability, supportability/availability for microgravity, integrated test and verification planning, and configuration and risk-management processes. Also, the Station's software independent verification and validation (IV&V) activity found and helped the program correct several critical flight software problems.

In the safety policy, requirements, and standards area, NASA updated its emergency program plan and developed new preparedness exercises to heighten its emergency response capabilities. NASA worked closely with the Federal Emergency Management Agency (FEMA) in planning and executing "Response '95," the largest peacetime emergency preparedness exercise ever accomplished. NASA developed an international agreement with Japan on hydrogen and oxygen propellant explosions tests. The work done under this agreement will result in further understanding and better definition of safety requirements for protecting against these types of explosions. Additionally, NASA promulgated standards and guidelines addressing software safety, orbital debris risk assessment, and risk assessment for large-scale programs.

NASA promoted International Organization for Standardization (ISO) 9000 as NASA's standard for quality management systems and inaugurated the NASA Engineering and Quality Audit and Advance Quality Concepts programs to improve the way it does business with its industry and educational institution partners. NASA conducted developmental work on new SR&QA tools, such as hand-held fire detection cameras, the spacecraft test effectiveness program, and improved electrical, electronic, and electromechanical parts qualification to set the stage for further reduced costs with improved safety and reliability in flight vehicles and payloads. The NASA-wide safety, reliability, maintainability, and quality assurance installation self-assessments and Headquarters spot checks continued to serve as effective assessment tools. NASA placed additional emphasis on safety training and professional development, and NASA's cost of quality workshops for program and system managers continued to provide value-added, practical tools for improving performance while reducing costs.

NASA's software assurance and software IV&V efforts included a comprehensive assessment of software for the ISS Interim Design Review 1 and software assessments for Space Shuttle flights and wind tunnel control systems. The NASA Software IV&V Facility in Fairmont, West Virginia, was selected to become the NASA Center of Excellence for software IV&V.

Other Space Technology

In FY 1995, NASA addressed the challenge of reducing mission costs without reducing performance and payoffs by focusing technology development on the following key objectives: (1) reducing the mass and increasing the efficiency of spacecraft systems to enable the use of smaller launch vehicles; (2) increasing spacecraft and ground system autonomy to reduce overall mission operations cost; and (3) exploiting microfabrication technology to develop miniaturized components and instruments with equal or better performance than current components and instruments. NASA continued to pursue these objectives through specific technology development programs.

In FY 1995, NASA completed the 2-kilowatt (of electric power) solar dynamic ground test demonstration, the first end-to-end demonstration of a complete solar dynamic power system designed for space operations. Engineers completed the program significantly ahead of schedule and under budget. The system performed as designed under conditions simulating the thermal and vacuum environment of low-Earth orbit. In FY 1995, Lockheed Martin adopted for commercial use an advanced arcjet spacecraft propulsion system, developed by NASA, because of its significantly reduced propellant use.

In FY 1995, NASA's instrument and sensing technology program demonstrated large-format infrared arrays, which can be produced for both Earth science and astrophysics mission applications. This included demonstration of a new 256 by 256 element array with the potential for reducing the mass, power requirements, and complexity of Earth-observing instruments in the 15- to 20-micron range, which is critical for studying Earth's environment from space. Progress in the development of microelectromechanical systems components in FY 1995 led to a flight demonstration of a microhygrometer that outperforms current, large instruments. Also in FY 1995, Hughes Danbury Optical Systems delivered the primary mirror for the advanced infrared telescope to JPL's cryogenic optical test facility. NASA's advanced infrared telescope will have twice the collecting area, half the mass, and one-third the diffraction wavelength of the previously flown Infrared Astronomy Satellite.

The instrument and sensing program also supported the development of a viable, commercial remote-sensing industry by supporting the prototyping of specialized packaging of space-based data products into usable, customer-defined information products. Researchers completed eight projects in FY 1995, including projects in agricultural production management, marine vessel surveillance, and gas pipeline monitoring. Scientists also began a variety of new cooperative projects, ranging from sensor development and desktop mapping software design to rangeland management and television weather forecasting.

In FY 1995, NASA's operations and autonomy technology program developed an artificial intelligence application that searches massive image data bases and finds phenomena of interest. This tool, when applied to astrophysics data, discovered 10 quasars in a small fraction of the time and cost it would have taken humans to analyze the data.

As a step toward the Mars Pathfinder mission, a NASA planetary rover conducted a 10-kilometer autonomous traverse across natural terrain, with human control limited to the designation of the vehicle's heading and end goal. The program also continued to develop, in conjunction with industrial partners, the robotically assisted microsurgery system, a robotic system for the precise manipulation of surgical tools for ocular surgery. These manipulations are constrained to a 1-cubic-inch work envelope and must achieve very high levels of precision and repeatability. NASA is developing such robotic surgery tools for potential telemedicine uses on long-duration human missions.

The Advanced Smallsat Technology program progressed towards NASA's first small spacecraft demonstrations, as systems integration work was completed on the "Lewis and Clark" satellites. At the end of FY 1995, each experimental satellite, which is no bigger than a console television set, was scheduled for launch in mid-1996. The Lewis spacecraft is to be the first "hyper-spectral" imaging system, with wide applications in Earth science and commercial remote sensing. NASA engineers have designed the Clark spacecraft to help city planners and developers evaluate sites and construction needs through the use of a very high-resolution optical element with stereo imaging capabilities. Both spacecraft are to carry additional instruments that will provide global atmospheric pollution dynamics information for NASA's MTPE. NASA managers hope to learn from the Lewis and Clark program how to reduce the development and operating costs of scientific spacecraft, while simultaneously increasing the yield of useful scientific data from them.

In FY 1995, NASA's space communications program accomplished an extensive number of experiments using NASA's Advanced Communication Technology Satellite. Researchers performed unique experiments in the areas of telemedicine and tele-education and demonstrated high rates of data transmission via satellite.

In July 1995, the DoD-sponsored Hercules project flew successfully aboard the Space Shuttle on mission STS-70. Jointly funded by the Naval Research Laboratory (NRL) and the Army Night Vision and Electronic Sensors Directorate, Hercules investigated the utility of multispectral video imagery to support DoD objectives. Using mostly commercially available instruments, Hercules recorded multispectral, geolocated images of Earth from space. DoD hopes to make further use of this project both from the Space Shuttle and the future ISS.

Mission controllers from the Ballistic Missile Defense Organization (BMDO) reestablished contact with the Clementine spacecraft in February 1995, after a software problem in May 1994 hampered communications with the satellite. Launched in January 1994, the Clementine mission was successful in terms of space-qualifying 23 advanced, lightweight technologies during its 17-month mission. During FY 1995, scientists continued to analyze data obtained from the mission's lunar mapping. They also investigated the exciting possibility that Clementine discovered ice trapped in a dark region of the Moon's south pole. The Clementine mission also provided scientists and the general public with unprecedented access to data by placing most of the information on the Internet. A single site maintained by the NRL, for example, averaged more than 800 accesses per day.

The Space Technology Research Vehicle (STRV)-1b program was nominally completed in June 1995, 1 year after its launch, but mission controllers extended the program to evaluate the Satellite Communications Protocol System, an initiative sponsored by the U.S. Space Command, NASA, and Britain's Ministry of Defence. The successful collaboration on the STRV-1b program resulted in the establishment of a second joint venture, the STRV-2 program, which is to combine a British midwavelength infrared optical system with a U.S. vibration isolation system to demonstrate the ability to detect nonafterburning aircraft from space and to acquire the data needed for the development of missile tracking software.

Sandia National Laboratories and Los Alamos National Laboratory continued to provide nuclear explosion sensors for integration onto DoD GPS and defense support program spacecraft. These sensors are designed to detect, identify, and locate any atmospheric or near-Earth space nuclear explosions. The sensors are used to verify international compliance with nuclear test-ban treaties, to monitor nuclear proliferation, and to meet military needs in the event of a nuclear attack.

In FY 1995, NASA's Office of Space Access and Technology formed the Advanced Concepts Office (ACO) to identify and develop new, far-reaching concepts that may later be applied in advanced technology programs. The ACO initiated a wide-ranging program of feasibility studies and experiments in FY 1995 in areas such as affordable in-space transportation, space solar power, highly reusable space transportation, very large and lightweight adaptive optics, orbital debris removal, International Space Station downmass disposal using tethers, structureless cooperating space swarms, and very large lightweight structureless antennas. The ACO also formulated a process for advanced concept creation, external to NASA, and issued an initial CAN solicitation for the Advanced Concepts Research Projects program. In addition, the ACO defined a potential process for competitive creation of innovative concepts by NASA's own inventors. Moreover, the ACO supported the NASA Administrator's Seminar Series, which covered a wide range of cutting-edge questions in science and exploration. NASA also created the Virtual Research Center concept, involving a dedicated collaborative computing environment for NASA advanced concepts studies. The ACO began developing this innovative Internet-based tool for geographically distributed team activities.

Technology Transfer

In FY 1995, NASA released the "Agenda for Change," a comprehensive policy document that sets out a new way of doing business for NASA's transfer of technology to the private sector. NASA also established a new national computer system to track the technology transfer potential of NASA programs.

The following are just two of 1995's hundreds of instances of NASA's ongoing efforts to foster and transfer space and aeronautics technologies with secondary applications in the private sector:

- ❑ NASA's Langley Research Center (LaRC) introduced a new technology to reduce lives lost from carbon monoxide poisoning. LaRC granted licenses for a NASA low temperature carbon monoxide oxidation catalyst technology for specific commercial applications to three different companies. NASA engineers and scientists developed these catalysts to provide a capability for recycling carbon monoxide produced during the operation of closed-cycle carbon dioxide lasers in space environments. This technology recombines carbon monoxide, a potentially lethal gas to humans, and oxygen into carbon dioxide, a comparably harmless gas.

- ❑ Firefighters and other emergency rescue workers now have access to a new generation of emergency rescue equipment that weighs 70 percent less and is 70 percent cheaper than other similar rescue equipment. Hi-Shear Technology Corporation, using NASA technology, completed the development of a new generation of lightweight, hand-held, emergency rescue equipment specifically designed to allow for the rapid removal of auto accident victims. The Lifeshear incorporated NASA-developed pyrotechnical technology called the initiator or power unit. As the industry leader in developing pyrotechnic-actuated thrusters, explosive bolts, separation nuts, pin pullers, and cutters, Hi-Shear has supplied these items for nearly all of NASA's major deep-space missions over the past 23 years. The Lifeshear cutters weigh less than 15 pounds, are about 2 feet long, take about 30 seconds to set up, and require no pumps or motors for operation. In 1995, the Lifeshear cutter was used at the site of the Oklahoma City Federal Building disaster. After this successful use, FEMA immediately ordered 40 of the cutters and 7,000 of the initiators/power units. FEMA has also recommended the purchase of the Lifeshear cutters by all urban search-and-rescue groups throughout the United States.

FY 1995 also saw significant progress in NASA's ongoing efforts to develop and transfer technology with biomedical applications. Early in the fiscal year, NASA began a cooperative effort with the National Institute of Child Health and Human Development to exploit NASA's bioreactor technology. This effort has developed into a highly successful transfer of technology and expertise. Other NIH researchers have been using NASA technology to grow cultures of human lymph tissue to study the infectivity of the virus (HIV) that causes AIDS. NASA expanded on this activity by awarding grants to the Massachusetts Institute of Technology in Cambridge and the Wistar Institute in Philadelphia to transfer this technology to university researchers.

Working with technologies developed by the Ames Research Center (ARC), pediatric surgeons at the University of California at San Francisco initiated a program to use NASA-developed biosensor and telemetry technology to monitor the condition of fetuses with life-threatening congenital conditions. Ames shared its innovative technologies with surgeons at the university's Fetal Treatment Center, which expects to develop additional life-saving medical procedures because of its collaboration with ARC.

With support from the NSF, medical doctors and astronomers from Georgetown University, the Space Telescope Science Institute, and Johns Hopkins University formed a collaboration to apply computer software, originally crafted for HST, to look at the heavens for scanning digitized mammograms. Over recent decades, the processing of astronomical images has become very sophisticated, spawning techniques to reconstruct and filter images, as well as to detect faint objects. The collaborative project got its start when scientists realized that stars in the sky look remarkably similar to the signs of breast cancer, called microcalcifications, for which radiologists search. After having a radiologist point out the microcalcifications in two mammograms, a team of astronomers was able to find the signs of cancer in the other two images without being shown. Project scientists then proceeded to scan more mammograms to assess the utility of the technique on a broader scale and possibly use the software to detect other types of cancers.

Also in the area of breast cancer screening, NASA's Office of Life and Microgravity Sciences and Applications teamed with the National Cancer Institute (NCI) to cosponsor applied research and development projects designed to lead to new digital imaging techniques for the early detection of breast cancer. Innovative breast cancer imaging techniques that were recently selected from a NASA/NCI competitive solicitation are expected to lead to highly effective, low-cost diagnostic technologies. NASA scientists also initiated a partnership with the University of South Florida to use advanced signal detection techniques originally developed under the Search for Extraterrestrial Intelligence program for computer-aided breast tumor detection, which shows great promise for detecting tumors very early in their development at a low cost.

Rescue workers now have access to a new type of emergency rescue equipment that is lightweight and relatively inexpensive. The Lifeshear cutter incorporates NASA-developed pyrotechnical technology to allow for the rapid removal of auto accident victims. In FY 1995, the Lifeshear was used successfully at the site of the Oklahoma City Federal Building disaster.

The Biocomputation Center at NASA's ARC developed new computer methods for the three-dimensional reconstruction and visualization of inner ear balance organs based on very thin tissue slices. Discoveries associated with this work included the facts that balance organs are organized as simple representations of the brain and that sites of communication between neurons change when their environments are altered. Researchers also used the technique to visualize neurochemical systems in the developing and adult brain and to study how the brain learns by observing the changes in neurons during the learning process. Surgeons at Stanford University collaborated with NASA to use visualization software to develop virtual reality tools for planning surgery on children with craniofacial defects and for training surgeons.

In the industrial arena, General Motors (GM) and the University of Wisconsin conducted tests in the NASA Lewis Research Center (LeRC) 2.2-second drop tower to improve their understanding of droplet vaporization at high pressure, a process highly relevant to internal combustion engine operation. GM researchers were dissatisfied with their previous understanding of the fundamental nature of vaporization under high-pressure conditions and believed that only low-gravity testing would provide insight and basic data needed to improve their internal combustion engine designs.

NASA developed a stereo imaging velocimetry system for fluid physics experiments for use by a steel producer. NASA set up a Space Act Agreement with LTV Steel to study fluid flow for LTV's continuous casting processes. Using the stereo imaging velocimetry technology, LTV was able to analyze imperfections in the continuous casting processes and to determine which type of nozzle design to use to produce steel with fewer flow-induced defects.

Commercial Development and Regulation of Space Technology

Twelve licensed commercial space launches were conducted by U.S. launch operators during FY 1995, more than twice the number during the previous fiscal year and more than any year since commercial launching began in this country in 1989. These launches were licensed by DoT's OCST, which has the responsibility for overseeing this industry, particularly with regard to safety. This brought to 52 the number of U.S. commercial launches conducted since 1989. Of these launches, 24 have carried foreign or internationally owned payloads, many of them satellites bought from U.S. manufacturers. This combination has brought more than $2.5 billion to the U.S. balance of trade.

Since OCST's establishment in 1984, its responsibilities have been to license commercial space launches and the operation of launch facilities to protect the public health, safety of property, national security, and foreign policy interests of the United States, as well as to encourage, facilitate, and promote commercial space launches by the private sector. OCST has continued to grant licenses only to launch providers that demonstrate compliance with all safety regulations and have adequate insurance or financial resources to cover the maximum probable loss from a launch accident. OCST also is responsible for regulating the operation of commercial launch sites, such as those under development in Alaska, California, Florida, New Mexico, and Virginia.

In FY 1995, OCST issued a renewal of the operator license to Martin Marietta for Atlas launches and amended the operator license issued to McDonnell Douglas for Delta launches from Cape Canaveral. The Martin Marietta license subsequently was transferred to the merged Lockheed Martin Company. These actions extended the authority of the companies to conduct their respective licensed activities at Cape Canaveral for 2 years. OCST also extended the duration of several existing launch licenses to accommodate launch delays.

OCST issued a payload determination for the Multiple Experiment to Earth Orbit and Return (METEOR) reentry vehicle, in association with the license previously issued to EER Systems for the launch of a Conestoga vehicle from Wallops Island, VA. METEOR was the first attempt at ground-initiated reentry of an orbital spacecraft by a commercial operator. OCST worked to ensure that the reentry would be safe. At end of FY 1995, METEOR was awaiting an early launch.

During FY 1995, OCST processed more than a dozen maximum-probable-loss determinations, based on the actual risks associated with proposed launch activities. This activity was conducted under the amended Commercial Space Launch Act, which establishes comprehensive financial responsibility requirements for commercial launch activities licensed by OCST.

OCST supported research to revise the baseline assessment documents for each of the Federal launch ranges to reflect organizational and other changes. The revision for NASA's Wallops Flight Facility was nearly complete, and the one for the Cape Canaveral Air Station was under way at the end of FY 1995.

OCST began revising its programmatic environmental assessment (EA) for launch operations to reflect the introduction of new launch technologies and other changes. The EA originally was designed to make compliance with National Environmental Protection Act documentation easier for both the Government and industry. In FY 1995, OCST decided to adapt the EA into a more thorough programmatic environmental impact statement to support the environmental documentation requirements for licensing the operations of new launch sites.

OCST began a program to encourage and facilitate the development of voluntary industry standards for launch safety. The attempt to get away from military standards makes the development of voluntary standards more urgent. OCST also encouraged industry to address issues related to the certification of RLV's, including SSTO vehicles.

To support pending and anticipated applications for licenses to launch large constellations of communications satellites in low-Earth orbit (LEO), OCST researched collision risk and the effects of service disruptions caused by collision.

Representatives of OCST participated in various panels and forums concerning new launch systems, including RLV's, in anticipation of the regulatory issues they will present. OCST personnel also examined the possibility of employing GPS and other technologies to reduce tracking costs and augment automated range safety operations. Because of several important developments in the commercial space launch industry, OCST regulatory and policy responsibilities broadened during FY 1995. These factors include the following:

- New vehicle technology developments, such as RLV's and reentry vehicles, that are capable of transporting a payload from orbit back to a designated site on Earth
- Strategic partnerships between the United States and foreign launch companies, such as Lockheed Martin and its International Launch Systems Division formed by Lockheed and two Russian companies
- The development of new LEO constellations of small communications satellites
- The expected impacts of International Telecommunications Union deliberations on spectrum allocations for radio frequencies
- Policy development and analysis for international commercial launch trade agreements (for example, Russia, China, and Ukraine)
- New entrants in the international launch market, such as Ukraine, Japan, and India.

A major priority for OCST during this fiscal year was the updating of its original 1988 regulations. OCST drafted financial responsibility regulations and regulations governing commercial launch operators' licenses. In the spirit of "reinventing" Government, OCST's proposed new regulations were "reengineered" for flexibility, clarity, and consistency. These regulations should ensure greater involvement of the public and coordination with local, State, and other Federal agencies, while ensuring fairness to small and large businesses alike. In addition, OCST introduced a new, streamlined automated licensing application process. All of these factors are expected to bring about better, more effective regulations, which will minimize the regulatory burden for the commercial launch licensee.

A major policy accomplishment by OCST in FY 1995 was the development of the Implementation Plan for the Presidential National Space Transportation Policy that was adopted the previous fiscal year. OCST participated in an interagency working group, led by the White House Office of Science and Technology Policy (OSTP), in developing a National Space Policy. OCST also provided sustained, indepth support for and participation in five interagency working groups initiated by OSTP for the purpose of developing specific sections of the new National Space Policy.

During FY 1995, OCST staff served on the Common Spacelift Requirements Working Group, which prepared a report outlining space launch requirements for commercial, civil, military, and intelligence users. This working group also developed a Coordinated Technology Plan for space launch requirements. OCST supported several other OSTP initiatives, including a working group on transition strategies for the end of the century, which focused on the future of commercial launch activities in a free and open international market without the benefit of trade agreements with countries that are in transition from command to market economies.

The National Environmental, Satellite, Data, and Information Service (NESDIS), an NOAA unit, has been charged with administering a 1994 Presidential policy on commercial remote-sensing that allows private firms to build and operate high-resolution satellite imaging systems. NESDIS personnel issued licenses in FY 1995 to AstroVision, GDE Systems, and Motorola to build remote-sensing satellite systems.

At NASA, the Commercial Space Product Development program flew payloads on four of six Shuttle flights in FY 1995. These payloads included 16 flight experiments using Shuttle middeck lockers, Spacehab, and the second flight of the Wake Shield Facility. These research activities provided information for product developments in several industrial areas, including pharmaceuticals, medical devices, agriculture, ceramics, and metallurgy. Protein crystals grown in space allowed the characterization of alpha-interferon and Factor D, which could result in advanced drugs, while the results of the encapsulation of pancreatic islets could lead to new treatments for diabetes. The second flight of the Wake Shield Facility demonstrated epitaxial growth in a free-flying mode, obtained data characterizing the wake environment, and grew two types of epitaxial semiconductor films. The flight of Spacehab-3 included commercial experiments involving protein crystal growth, metal sintering, immune systems diagnostics, fluids mixing, biomedical applications, new polymer development, and plant growth. In protein crystal experiments, an attempt to regulate the growth of the alpha-interferon crystal successfully yielded a more effective formulation for potential pharmaceutical use, while work on polymers could result in clinical trials of new contact lenses developed by Paragon Vision Sciences Corporation. The Eclipse liquid metal sintering experiment on Spacehab-3 processed samples for a full hour—a duration essential for providing the defect-trapping information to enable comparisons with sintering processes on Earth. The first completely self-contained, space plant growth chamber was demonstrated, and wheat and mustard plants were shown to have growth patterns similar to those achieved in Earth's natural environment, thus validating chamber performance.

Also in FY 1995, NASA named the University of Alabama at Huntsville (UAH) as the recipient for the Launch Voucher Demonstration program under the Office of Space Access and Technology's auspices. UAH selected the commercial vendor EER Systems on a competitive basis. NASA managers selected six industrial experiments for this flight.

SPACE COMMUNICATIONS

Communications Satellites

During FY 1995, the Federal Communications Commission (FCC) coordinated and registered several launches of spacecraft for the International Telecommunications Satellite Organization (INTELSAT), a consortium of more than 130 countries that own and operate the world's most extensive global communications satellite system. INTELSAT launched its third INTELSAT VII series satellite (INTELSAT 703) on October 6, 1994, aboard an Atlas IIAS launch vehicle from Cape Canaveral, Florida. Deployed in the Pacific Ocean region, this satellite provided additional telephone, broadcasting, and private network capacity. INTELSAT also successfully launched its INTELSAT 704 spacecraft aboard an Atlas IIAS launch vehicle from Cape Canaveral, Florida, on January 10, 1995, and on February 25, 1995, the INTELSAT 704 satellite began commercial operations, providing enhanced satellite services, including digitally transmitted television programming to customers in the Indian Ocean region. The INTELSAT 704 provided much-needed capacity to satisfy increasing customer requirements in Asia, Africa, Australia, Europe, and the Middle East. Launched on March 22, 1995, the INTELSAT 705 spacecraft began operation on May 8, 1995, in the Atlantic Ocean region and provided enhanced communications capabilities for INTELSAT customers in Latin America. The INTELSAT 706, the first INTELSAT VII-A spacecraft, was launched successfully on an Ariane launch vehicle on May 17, 1995.

The FCC also authorized several launches of global communications satellites by PanAmSat, the first private company to provide global satellite services. PanAmSat's PAS-4 satellite (designated PAS-6 by the FCC) was launched on August 3, 1995, aboard an Ariane 4 rocket and began broadcast and telecommunications services throughout Africa, Europe, the Middle East, and south Asia in September 1995. The PAS-3 satellite (designated PAS-2 by the FCC) was destroyed during a launch failure on December 1, 1994.

Similarly, the FCC authorized the launch of the Orion I communications satellite, which took place on November 29, 1994. Built for Orion Atlantic Satellite Services, an international business consortium, this spacecraft began providing multiple spot-beam coverage and broad-beam transatlantic and regional coverage in North America and across Eastern and Western Europe in early 1995.

On January 12, 1995, the FCC allocated spectrum in the 2,310- to 2,360-megahertz band for satellite digital audio radio services. This domestic allocation is in accordance with the international allocation made at the 1992 World Administrative Radio Conference. This action is the first step toward providing the American public with new multichannel, multiformat digital radio service with sound quality equivalent to compact disks.

As the principal advisor to the President, Vice President, and the Secretary of Commerce on telecommunications issues, the National Telecommunications and Information Administration (NTIA) undertook a number of policy initiatives involving satellites and other space-based telecommunications systems during FY 1995. For example, NTIA provided policy guidance related to the potential restructuring of the International Mobile Satellite Organization (INMARSAT) and INTELSAT during FY 1995. Specifically, NTIA analyzed INMARSAT's proposal to expand beyond mobile maritime and aeronautical services to include a global, hand-held telephone system called INMARSAT P. NTIA advocated a structural separation between INMARSAT and its proposed new commercial affiliate, enabling INMARSAT to enter new markets while still maintaining a level playing field for other similar global communications ventures.

During FY 1995, NTIA continued to support the satellite telecommunications network known as PEACESAT (Pan-Pacific Educational and Communications Experiments by Satellite), which provides social, environmental, health, and educational exchanges in 21 countries within the Pacific Basin. NTIA secured the use of the GOES-2 satellite from NOAA to ensure the continuation of PEACESAT services after the GOES-3 satellite became unavailable because of limited station-keeping fuel. NTIA also supported the design and testing of digital ground terminals to bring increased voice, data, and compressed video services to the Pacific islands. The Federal Emergency Management Agency (FEMA) and DoI agreed to utilize PEACESAT as the backbone for an emergency management system in the U.S.-affiliated areas of the Pacific.

NTIA also represented U.S. scientific users of the radio frequency spectrum in various domestic and international regulatory forums, such as those sponsored by the International Telecommunications Union (ITU) and the Radio Technical Commission on Aeronautics. In particular, NTIA played a key role in U.S. preparations for the World Radiocommunications Conference 1995 for new spectrum allocations that took place from October to November 1995. During FY 1995, NTIA prepared for this ITU-sponsored conference by working with other Federal agencies and the private sector to guide the development of consistent U.S. policies on such key issues as mobile satellite service allocations.

As designated by the President and the Secretary of Commerce, NTIA authorizes and manages all Federal agency use of the electromagnetic spectrum. During FY 1995, it authorized 20 future Federal satellites and space systems for frequency use. NTIA continued to chair an interagency committee that reviews domestic and foreign space systems to determine the possible impact and electromagnetic compatibility with Federal telecommunications networks.

Through its administration of the communications spectrum for the Government (the FCC continued to regulate the spectrum for non-Government users), NTIA prevented the interference of commercial systems, such as communications satellites, from weather, scientific, and national security communications satellites. NTIA assisted the commercial sector in coordination with Federal users of the radio frequency spectrum so that industry could make quick use of new allocations. Specifically, NTIA helped Volunteers in Technical Assistance to clear regulatory hurdles with other Federal agencies after their original satellite contractor withdrew, causing a potential design change that could have interfered with Federal satellites. NTIA personnel also brokered a formal agreement with the FCC and the FAA that allowed mobile satellite service systems to be licensed while still protecting GPS users from interference, especially in aviation and maritime settings.

On the Advanced Communications Technology Satellite (ACTS) program, NTIA demonstrated advanced telecommunications switching technology to improve communications capabilities of underserved citizens, especially in rural areas. Engineers at the Institute for Telecommunications Sciences, part of NTIA, developed an Earth station and made it available to other researchers for experimentation.

During FY 1995, DoD approved for implementation an initiative called the Global Broadcast Service (GBS). This system capitalizes on commercial direct broadcast satellite technology to provide high data-rate information, such as imagery, weather, and logistics, to warfighters. GBS is expected to provide two key improvements over existing DoD systems—information to very small user terminals and reduction of the need for multiple transmissions because GBS sends data to many users simultaneously.

The DoD refurbishment of its UHF satellite constellation proceeded on schedule with the launch of two Navy UHF Follow-On (UFO) satellites during FY 1995. The overall design architecture calls for two UFO's per coverage area, for a total of eight with an additional on-orbit spare. UFO-4 was launched successfully on January 28, 1995, and assumed operational status in a geosynchronous orbit over the Pacific Ocean. On May 31, 1995, UFO-5 was launched successfully into a geosynchronous orbit over the Indian Ocean and became operational on August 1, 1995.

Because current DoD systems lack sufficient capacity to support the enormous communications requirements for joint command operations, the Navy has pursued the use of commercial satellite communications systems to resolve this deficiency. The Chief of Naval Operations' Challenge

Athena project demonstrated successfully that commercial satellite capability can be a viable, cost-effective augmentation of existing, overburdened military satellite systems. Challenge Athena proved itself as an innovative space system solution, using commercial narrow-band and wideband satellite communications to provide for the timely delivery of high-volume national primary imagery data to afloat warfighters. During a 6-month deployment of the *U.S.S. George Washington* battle group, Challenge Athena delivered more than 6,600 near-real-time images to battle group warfighters. It further provided two-way connectivity for a variety of spinoff applications, including telephones, telemedicine, and teleconferencing.

The Navy's Situational Awareness Beacon with Reply (SABER) system successfully completed a concept demonstration exercise and technical evaluation in March 1995 and an all-service evaluation and test exercise in September 1995. SABER is a satellite communications-based beacon assembly that passes unit identification and GPS positions to command-and-control nodes and warfighting platforms. DoD hopes that SABER will significantly upgrade its combat identification ability.

During FY 1995, the Defense Satellite Communication System (DSCS) continued to serve as the long-haul, high-capacity communications system for worldwide command and control of the U.S. armed forces. The DSCS program successfully launched a DSCS III satellite in July 1995, which serves as a replacement for an older DSCS III. Five other DSCS III satellites in storage at the end of FY 1995 were scheduled for future launches. At the end of FY 1995, there were five DSCS operations centers and five auxiliary satellite control terminals worldwide, operated and maintained by the U.S. Army Space Command. The Heavy Terminal/Medium Terminal (HT/MT) modernization program began upgrading the first DSCS HT/MT's in FY 1995 to extend the mission life of these ground-based assets and additional 15 years. DSCS space and ground resources supported a wide variety of high-priority missions, such as military activities in Haiti, Bosnia/Herzegovina, Somalia/Kenya, Saudi Arabia/Kuwait, Iraq/Turkey, and various Presidential trips.

Space Network

The seventh Tracking and Data Relay Satellite (TDRS) was launched successfully aboard Space Shuttle *Discovery* on July 13, 1995. Built by TRW, Inc., to replace the TDRS-B lost in the *Challenger* accident, this spacecraft successfully completed all functional and characterization tests in an interference-free orbital location and is to serve as the reserve spacecraft in the western location.

In White Sands, New Mexico, the Danzante ground terminal, formerly known as the second TDRS System ground terminal became fully operational on March 10, 1995. The Danzante assumed all user service and TDRS satellite control functions, while Cacique, the original terminal, began undergoing modernization. Cacique was scheduled to return to service in 1996, providing a dual terminal complex at White Sands. Dual terminals will eliminate the ground station as a single point of failure in space network operations, provide the capability to extend the useful life of partially failed spacecraft, and reduce life-cycle costs through operating efficiencies.

Portcom, a new portable, low-power, low-cost transmitter/receiver was developed in FY 1995. This instrument takes advantage of the high signal strength and global coverage of the TDRS and has the potential to expand communications applications to multiple dispersed geographic locations using the TDRS. Originally built for the Globe student communications project, the hand-held or camera-mounted device successfully transmitted pictures from Antarctica via the TDRS.

Ground Networks

Ground-based telecommunications facilities are used to provide telemetry, command, and navigation services to a number of NASA and international spacecraft, such as the Space Shuttle, Earth-orbiting spacecraft, planetary orbiters, and spacecraft on deep-space missions, in addition to supporting suborbital sounding rocket and balloon flights. Accomplishments during FY 1995 included providing services to the Ulysses spacecraft during its observation of the polar regions of the Sun, the probe release and orbital deflection maneuver of the Galileo spacecraft in preparation for its encounter with Jupiter, and approximately 50 other spacecraft missions, 1,500 aeronautical test flights, 30 sounding rocket launches, and 22 atmospheric balloon flights. NASA made capacity and capability enhancements to the telecommunications facilities to ensure the fulfillment of NASA's science mission requirements.

Mission Control and Data Systems

The past year marks several important accomplishments for Mission Control and Data Systems, which provide the control and performance analyses of NASA's robotic Earth-orbiting spacecraft. The Spacelab Data Processing Facility, previously located at the Goddard Space Flight Center, was consolidated successfully at the Marshall Space Flight Center, resulting in a cost savings of more than 50 percent in the processing of Spacelab and Shuttle-attached payloads data. In FY 1995, NASA Mission Control and Data Systems provided 39,500 hours of mission control services to 11 on-orbit science missions.

AERONAUTICAL ACTIVITIES

Technological Developments

NASA managers accelerated their work on the High-Speed Research (HSR) program after awarding Phase II industry contracts in the fall of 1994 for the development of airframe, propulsion, and flight deck technologies. The objective of the HSR Phase II program is to conduct research and develop the high-leverage, high-risk technologies essential for an environmentally compatible and economically viable supersonic airliner or High-Speed Civil Transport (HSCT).

NASA and its industry partners completed wind tunnel testing and computer analyses and simulations to verify the ability of an HSCT to satisfy the Federal Aviation Regulation 36 Stage 3 noise standards. To assess noise and thrust performance, as well as to validate computer models, NASA conducted high-lift engine aeroacoustics technology tests in the 40- by 80-foot wind tunnel of the Ames Research Center (ARC). The results confirmed the computer predictions and increased NASA's confidence in the ability of the nozzle and high-lift concepts to meet stringent noise rules. In another noise-reduction effort, NASA continued its research and testing of advanced lightweight composite materials that could be used as liners for exhaust nozzles. NASA scientists and engineers measured the acoustic performance of several candidate materials in acoustic cells. The results indicated that a 3- to 4-decibel (dB) reduction in total jet noise is possible if designers used those materials as acoustic liners. Future plans include long-term testing in a high-temperature environment to assess the durability of these materials.

On the Russian Tu-144 project, NASA and its partners made significant progress in modifying this supersonic flying testbed, which will be used to conduct flight research and to validate high-speed research computer models and simulations. Technicians installed upgraded digital flight recorders, instrumentation, and engines.

The goal of NASA's fly-by-light/power-by-wire (FBL/PBW) program is to provide technology for lightweight, highly reliable, electromagnetically immune control and power management systems for advanced subsonic civil transport aircraft. Optical technologies are immune to electromagnetic interference and eliminate the threat of electrical sparking. PBW eliminates the need for centralized hydraulic and pneumatic systems, variable-engine-bleed air systems, and variable-speed constant-frequency drive systems found in secondary power systems in today's aircraft. The use of FBL/PBW results in significant weight savings, reduced maintenance, more efficient engine operation, and reduced complexity. The Boeing Commercial Aircraft Group completed the FBL system design and began a detailed design at the end of FY 1995. Additionally, managers selected the PBW-controlled power management and distribution system architecture from 10 prospective concepts.

In the area of aircraft noise, NASA established an objective of achieving a 10-dB noise reduction compared to 1992 levels, and a team of noise technology specialists from industry, academia, and Government began work to achieve that objective. During FY 1995, NASA, Pratt & Whitney, and Allison Engine conducted jet engine noise tests at the NASA Lewis Research Center (LeRC) aeroacoustic propulsion laboratory to explore engine air mixer designs that reduce noise on low and moderate bypass ratio engines. NASA obtained acoustic, aerodynamic, and structural data in tests performed at the LeRC 9- by 15-foot low-speed wind tunnel, using a research model of Pratt & Whitney's advanced ducted propulsor. Boeing performed a diagnostic fan test under joint LeRC/Langley Research Center (LaRC) sponsorship to identify the dominant noise sources from engine fans. There has been strong coordination among Government, industry, and academic groups in planning and transferring technologies within the noise reduction program.

The FAA participated with NASA in a series of joint noise reduction and emissions reduction research initiatives. The two agencies continued implementation of the joint subsonic airplane noise reduction technology research program and reported progress to Congress. The two agencies also jointly assessed the state of quiet aircraft technology for propeller-driven airplanes and rotorcraft. In the area of engine emissions, the FAA continued its participation in NASA's Atmospheric Effects of Aviation project to develop a scientific basis for assessing the impact of aircraft emissions on the environment, particularly on the ozone layer and global climate change. The two agencies also began a cooperative program for the development of engine exhaust emissions certification standards and procedures for future subsonic turbojet engine technology. In the area of aviation environmental assessment, the FAA released a significantly improved new computer model.

NASA worked with its industry partners on developing active noise control in aircraft engines. General Electric completed a test in the LeRC aeroacoustic propulsion lab, where it demonstrated an active noise control concept using a large, low-speed fan. In addition to experimental work, NASA performed several analyses to predict jet and fan noise and applied them to test hardware to validate the software code. Pratt & Whitney, on a contract to NASA, developed a new fan tone prediction code, called the Theoretical Fan Noise Prediction System. General Electric developed a fan broad-band noise prediction code and an improved version of a software code to predict jet noise.

Engineers at NASA's LaRC developed improved prediction codes for engine fan noise, an interior noise control concept using an active trim panel, and two new ducted fans, which incorporate active noise control. LaRC engineers used the prediction codes, which included nacelle effects, to develop noise control concepts that they will validate in a series of wind tunnel tests. NASA engineers also conducted a laboratory experiment using active devices to control interior aircraft noise in a model airplane fuselage in which control devices were attached to the interior trim panels. The results were encouraging. One ducted-fan model in which error microphones were installed demonstrated global far-field fan noise reduction. Researchers used the second duct-fan model, a high-power, high-fidelity engine simulator, in an experiment in LaRC's 14- by 22-foot wind tunnel to investigate the symmetry of radiated noise in the wind tunnel environment. Scientific investigators also conducted a one-fourth-scale model of the ARC flap edge experiment to develop acoustic and flow measurement techniques to be used in a 1996 follow-on, one-half-scale test to investigate the scaling of airframe noise. NASA personnel, in cooperation with their industry colleagues, performed a benchmark airframe noise test in the ARC 7- by 10-foot wind tunnel. The team employed microphone array technology to make successful acoustic measurements of a model semispan flap in a wind tunnel environment. Results of the test indicated that the flap edge is an important source of airframe noise. Researchers also conducted an airframe noise test in the 40- by 80-foot wind tunnel on a DC-10 model.

NASA's Advanced Composite Materials Technology program made significant progress in FY 1995 toward scaling up existing technology by designing, fabricating, and testing a full-scale wing section and fuselage panels under simulated flight loads. Specific program objectives are to verify composite fuselage and wing structure designs that will have an acquisition cost of 20 to 25 percent less (instead of the current twice as much) and weigh 30 to 50 percent less than the current aluminum aircraft with the same payload and mission. NASA tests of composite aircraft elements and panels indicated outstanding damage tolerance, durability, and weight savings compared to aluminum structures.

Engineers working on NASA's Advanced Subsonic Technology program, in cooperation with U.S. industry, developed propulsion technology that will help increase the competitiveness and market share of the U.S. propulsion industry and reduce the environmental impact of future commercial engines by reducing exhaust emissions. This program has helped protect the current base of highly skilled U.S. jobs and will seek to recover some of the 50,000 jobs recently lost from industry downsizing. NASA researchers have been developing new propulsion systems technology to reduce overall direct operating costs of future commercial transports by 3 percent, which represents the profit-and-loss margin for a U.S. airline. NASA started building a new and unique high-pressure and high-temperature combustor facility at LeRC to provide U.S. engine manufacturers the ability to test their new low-emission combustors.

Researchers working on NASA's civil tiltrotor program have been building the technological foundation for a vertical takeoff and landing commuter airliner of the future. In 1995, they conducted the fifth civil tiltrotor simulation experiment on the ARC Vertical Motion Simulator. The experiment investigated power requirements for a tiltrotor transport with one engine inoperative during terminal area operations. The aircraft required only a 600-foot paved "rollway" for takeoffs and landings, using simulated engine power that is typical of current designs. Using performance parameters typical of a higher rated engine made vertical operations possible from a much shorter paved surface and allowed the minimum visibility requirements to be reduced to a 100-foot ceiling.

During FY 1995, a general aviation task force subcommittee of the NASA Aeronautics Advisory Committee reviewed the status of the industry. The subcommittee recommended that NASA revitalize its general aviation program and make available to the community its "world-class tools," such as wind tunnels, computer simulations, engine test cells, and material property labs. In addition, the subcommittee recommended that NASA's technology programs for general aviation be balanced with respect to industry needs in the following four areas: aerodynamics; aeronautical systems; structure and materials; and propulsion, noise, and emissions. To those ends, NASA took the lead in an effort to revitalize the U.S. general aviation industry. NASA entered into Joint Sponsored Research Agreements that are managed and implemented primarily through industry-led consortia. An Advanced General Aviation Transport Experiments consortium was initiated to revitalize market growth for intercity transportation in small aircraft.

FAA personnel also cooperated with their NASA colleagues on general aviation programs of mutual interest, including innovative aircraft design, new cockpit display and control technologies, enhanced ground/cockpit information systems, noise reduction, advanced general aviation transport experiments, the Atlanta short-haul transportation system, the short-haul civil tiltrotor, situational awareness for safety, and advanced aeronautical decision making. FAA scientists continued their research with NASA's ARC on steep-angle approach profiles to reduce rotorcraft noise.

NASA and its industry partners also completed Phase I of the Atmospheric Effects of Stratospheric Aircraft flight campaign. Flights of the NASA ER-2 high-altitude aircraft, carrying as many as 16 instruments to measure reactive and inert trace gases, aerosols, temperature, pressure, winds, ultraviolet light, and temperature profiles, provided new observations to diagnose the chemistry, physics, and fluid motion of air in the lower stratosphere. These observations assessed the environmental effects of a fleet of HSCTs and will be used to support the development of emissions standards for the HSCT.

Managers working on the environmental assessment element of NASA's advanced subsonic technology program began establishing a scientific basis to assess the atmospheric chemistry and climatic impact of subsonic aircraft. A NASA/industry/university team has established experimental techniques for characterizing the trace chemistry of engine exhaust emissions. In FY 1995, the team studied a military engine in an altitude simulation chamber at the Air Force's Arnold Engineering Development Center. A ground-based laser radar (lidar) instrument was used at LaRC to study the interaction of engine exhaust and wing vortices from the NASA Boeing 737 Transport Systems Research Vehicle (TSRV) aircraft. NASA's Wallops Flight Facility T-39 aircraft gathered flight measurements of related chemical effects resulting from those interactions.

The joint X-31 enhanced fighter maneuverability cooperative effort, involving the Navy, Air Force, NASA, Rockwell International, the German Defense Ministry, and Daimler Benz Aerospace, was completed in FY 1995. These partners initiated the program to assess the impact of thrust vectoring during slow-speed, poststall maneuvering and later was expanded to investigate other key issues. In FY 1995, this two-aircraft program set a new X-plane productivity record by accumulating 580 total research flights. The final activity for this flight research program was a flight demonstration at the Paris Airshow in June 1995. Earlier in the year, researchers investigated aircraft controllability issues in low-speed flights to simulate Navy carrier landing operations using a "quasi-tailless" configuration on the X-31. This activity supported the requirements of the Joint Advanced Strike Technology (JAST) program office in DoD. In July 1995, the Smithsonian Institution announced that the X-31 International Test Organization was the winner of its 1995 Air and Space Museum Trophy for Current Achievement.

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Scientists involved with NASA's SR-71 aircraft testbed program conducted several flights in FY 1995 for aeronautical research to assist industry in developing an HSCT aircraft. NASA personnel successfully completed a research project to study the propagation of shock waves caused by the SR-71 sonic boom. Project personnel also investigated the effects of Mach number, altitude, and aircraft gross weight to validate analytic models and to investigate methods of softening sonic booms. The congressionally mandated Air Force SR-71 reconnaissance reactivation program began during FY 1995 and received extensive support from NASA's Dryden Flight Research Center (DFRC). The reactivation program included the training of Air Force pilots by NASA instructors.

Aircraft designers structured the F-18 high-alpha technology program to achieve an understanding of airplane aerodynamics at high angles of attack. The DoD/NASA program investigated the effects of thrust-vectoring and mechanical strakes on the air flowing around the aircraft. An inlet distortion data base was developed to validate inlet computational fluid dynamics codes and to develop design methods for engine inlets that are tolerant of high-alpha maneuvers. The researchers used flight research, wind tunnel research, and computational fluid dynamics modeling. The program used a highly instrumented F-18 aircraft specially outfitted with two new flight control concepts.

Designers created the F-18 systems research aircraft to help identify and flight-test advanced technological concepts. In FY 1995, technicians continued to flight-test and successfully operate a "smart actuator," installed as a replacement for a conventional aileron actuator. A second element of the program involved the installation of a self-contained electro-hydrostatic aileron actuator. Researchers continued to conduct flight tests in FY 1995 on the fiberoptic "fly-by-light" control systems programs. NASA personnel also flight-tested a structural integrity monitoring system and a flush-mounted air data system.

During FY 1995, NASA's flight research instrumentation and test techniques program acquired pressure data associated with the interaction of shock waves on the boundary layer. Researchers gathered the data using 12 special "kulite" pressure sensors capable of measuring 100,000 samples each per second. Scientists who performed other related experiments investigated special tape that is residue-free and resistant to high temperatures and technologies to attach heat gauges and thermocouples to the Russian Tu-144 supersonic transport aircraft.

The Environmental Research Aircraft and Sensor Technology alliance, established in September 1994, formed a new partnership among six companies in the remotely piloted aircraft industry and Government. The alliance identified two key missions as being critical to the collection, identification, and monitoring of environmental data. The first critical mission was to achieve 80,000 to 100,000 feet carrying an instrument payload of 500 pounds for a minimum of 2 hours. The second was to achieve 50,000 to 75,000 feet carrying a payload of 1,000 pounds for a minimum of 96 hours. Scientists in cooperation with ARC have proposed 10 environmental science sensor designs for future development. Scientists flew two remotely piloted aircraft this year at DFRC. One was the "Perseus A," which used an internal combustion engine and carried liquid oxygen to achieve an altitude of 50,000 feet. The second, known as "Pathfinder," was powered by electrically driven propellers and sported solar cells mounted atop its 100-foot-long wing to power the propellers. The "Pathfinder" began flight operations in the fourth quarter of FY 1995 and achieved a solar-powered world altitude record of 50,500 feet.

In a cooperative effort with the Orbital Sciences Corporation, researchers equipped an L-1011 transport aircraft with 1,000 "tufts" resembling small pieces of string or thread on top of the right wing. The aircraft will be used for research to optimize the deflection of wing flaps during cruise flight. In a separate flight research activity, investigators demonstrated Propulsion Controlled Aircraft (PCA) technology in-flight on an MD-11 airliner. The PCA system was developed to provide the pilot with a way to fly an aircraft if its normal flight controls were disabled by modulating engine thrust to control the flight path of an aircraft. Researchers continued to develop the PCA concept as a result of several airplane crashes in which the hydraulic systems, used to power the flight controls, became disabled.

The NASA Short Takeoff and Vertical Landing (STOVL) technology program was conducted in support of the DoD JAST program. The first element of the NASA program involved the Vertical/Short Takeoff and Landing (V/STOL) Systems Research Aircraft (VSRA) Harrier aircraft, equipped with an integrated flight propulsion control system, cockpit controls, and display systems. During FY 1995, investigators completed most of their research tests. NASA personnel enhanced technology transfer by inviting industry engineers and pilots to participate in the flight experiments and the ground-based simulations. A second major element of the STOVL program consisted of aerodynamic testing at NASA research facilities of the STOVL configurations and components. Researchers designed these tests to help the JAST program select two contractor teams for the next phase of the program.

The NASA High Performance Computing and Communications (HPCC) office's primary role in the Federal HPCC program includes leading the development of applications software and algorithms for scalable parallel computing systems, which will increase system performance to the sustained teraFLOPS (10^{12} floating point operations per second) level for NASA applications. NASA continued to develop and evaluate high-performance computing, communications, and information technologies and to effect the transfer of these technologies into use for national needs. NASA made progress toward solving its "grand challenge" research problems in areas such as aerospace vehicle design, remote communications, and Earth science. NASA HPCC personnel also continued their research in distributed high-performance computing using high-performance workstations. The objective of this research is to dramatically decrease the costs of many high-performance computing requirements while ensuring reliable performance on workstations in diverse geographic locations.

The Information Infrastructure Technology and Applications (IITA) component of the HPCC program continued to broaden the program's public outreach and furthered the development of a Global Information Infrastructure (GII) by supporting research and development in education, digital library technology, and access to Earth and space science data. The IITA efforts comprise the development of critical information technologies and the application of these technologies to the "national challenge" problems to which the application of HPCC technology can provide large benefits to all Americans. Accomplishments in IITA during FY 1995 include the opening of a new Internet World Wide Web site called "The Observatorium" to assist students, teachers, and researchers in accessing many of the applications, technologies, and data bases developed by NASA for use on the Internet in new and stimulating ways. Many of the new digital library technologies developed in the IITA efforts have begun to be demonstrated in new remote-sensing data base applications and have proven to be valuable to furthering GII development, especially for kindergarten through grade 12 education.

The Computational AeroSciences (CAS) component of the HPCC program supported the installation of sophisticated new computers at ARC. These new systems have augmented other scalable parallel computers to provide research platforms for systems software, virtual wind tunnels, and other aerospace and manufacturing projects. The success of these CAS projects has led to significant enhancements in design support and computer simulation of aerodynamic performance and, therefore, should lead to more efficient and cost-effective aircraft and spacecraft design.

The numerical aeronautics simulation facility at ARC continued its improvements during FY 1995 in support of advanced research requirements in the aeronautics community. Many aerospace industry leaders already have attributed major cost savings to breakthroughs in this facility, which is considered to be the Nation's model for future high-performance computer centers.

The Navy and the Marine Corps continued to develop the V-22 Osprey tiltrotor aircraft in FY 1995. Technicians successfully joined the first production-representative V-22 Osprey fuselage in August 1995, marking the validation of the Osprey's design and manufacturing techniques. By incorporating lessons learned in the V-22's full-scale development phase as well as new breakthroughs in manufacturing technology, this aircraft is more than 1,500 pounds lighter and almost 30 percent less costly than an earlier design.

During FY 1995, DoD continued to support the joint NASA/DoD/industry National Wind Tunnel Complex (NWTC) activity at NASA's LeRC. If pursued, the NWTC should provide the United States with high-productivity, high Reynolds number test facilities that will be the world's best in testing aeronautical systems.

The Darkstar unmanned aerial vehicle was unveiled at the contractor facility in Palmdale, California, in June 1995. The first project to be executed under new authority granted to the Advanced Research Projects Agency (ARPA) for unprecedented Government-industry collaboration, this vehicle is designed to be an affordable, low-observable tactical reconnaissance vehicle that can operate in the current military force structure. NASA's DFRC continued to provide flight evaluation support on the Darkstar program.

Air Traffic Control and Navigation

In FY 1995, the FAA's Advanced Automation System (AAS) program underwent major restructuring to contain cost growth and minimize delays, and several new systems were introduced. The Display Systems Replacement program has begun to replace aged display channels, controller workstations, and network infrastructure by providing control room platforms for transition into other planned user benefit enhancements. Previously suspended, the Display Channel Complex Rehost program restarted its work to rehost existing display channel complex software from obsolete computer hardware to a new, more reliable and maintainable computer system. The FAA ordered a new digital Voice Switching and Control System for all air route traffic control centers and the FAA Academy to replace 30-year-old equipment. That project completed deployment readiness review and passed operational testing and evaluation during FY 1995. FAA personnel also continued work on the Standard Terminal Automation Replacement System to provide for any size terminal radar control (TRACON) while making maximum usage of standard commercial software and components. Engineers also made progress on the Automated Radar Terminal Systems program and the Tower Control Complex program for computer automation.

During FY 1995, the U.S. GPS achieved the final operating capability for civil aviation usage, and the FAA continued to certify additional GPS receivers. In August 1995, the FAA awarded a contract to Wilcox Electric Incorporated for the Wide Area Augmentation System (WAAS), a network of ground stations and communications systems designed to enhance the integrity and availability of GPS signals. The FAA's GPS-Navigation Integrated Product Team, with the FAA Technical Center, established the National Satellite Navigation Test Bed to continue operational demonstrations of evolving augmentation technologies and to validate developing software by the WAAS contractor.

In the military arena, GPS continued to be deployed fully, with complete worldwide availability to the U.S. armed forces. GPS allows accurate, instantaneous positioning for military forces and supports a new generation of smart, highly accurate weapon systems. Of particular note in FY 1995, DoD began to integrate GPS into the survival radios for U.S. pilots, allowing rescue forces to locate and communicate with downed personnel without compromising their location. The Army agreed to buy 95,000 GPS sets for their forces, while the Navy and Air Force followed similar paths.

Engineers at the Institute for Telecommunications Sciences, part of NTIA, were instrumental in developing a national plan to augment navigation signals from GPS, a satellite program managed by DoD. By providing more accurate and reliable GPS signals, a wide variety of transportation modes will be served, and a large economic and technological impact is expected to occur.

The FAA continued to conduct flight tests for developing criteria for nonprecision GPS approach terminal instrument procedures to be employed at heliports. This effort resulted in 35 lives being saved in 1 year at a single test site in Chattanooga, Tennessee, where the world's first helicopter nonprecision GPS approach was certified. Because a helicopter was able to arrive quickly at the trauma center under poor weather conditions, these lives were saved. The FAA is participating with NASA, DoD, and industry to promote and expand the U.S. rotorcraft technology base to improve safety and expand operations. The FAA is also working with the Civil Tiltrotor Development Advisory Committee to ascertain the pros and cons of developing a civil tiltrotor transportation system in the United States.

FAA personnel continued their work on the multielement Terminal Air Traffic Control Automation (TATCA) program, which provides computer automation to assist controllers in traffic flow management in the airspace surrounding major airports. This automation technology benefited users through improved airspace capacity, reduced delays, fuel savings, and enhanced controller productivity. The Converging Runway Display Aid (CRDA) component of TATCA allows continued use of paired aircraft on intersecting runways during instrument meteorological conditions. After successfully implementing CRDA at six airports, FAA personnel proceeded to adapt it for five additional terminal facilities. During FY 1995, engineers completed the first research and development phase of the controller automated spacing aid, which enhances CRDA capabilities to separate precisely aircraft that are on merging paths. The third main element of TATCA is the Center-TRACON Automation System (CTAS), a package of software components that was developed by the FAA and NASA. The CTAS design strategy shifted from individual software development to an integrated packaging approach with other traffic flow management products. FAA personnel would like to integrate CTAS with other traffic flow management systems, such as the automated enroute air traffic control system, the departure sequencing program, the surface movement advisor, and the traffic management system.

NASA and United Airlines conducted flight tests to evaluate and validate a software tool called the Descent Advisor, one of the elements that make up CTAS. CTAS increases the efficiency of air traffic control by giving flight controllers a better awareness of traffic flows. NASA's Boeing 737 TSRV flew 24 CTAS test runs in the Denver terminal area to identify and quantify sources of prediction errors in the Descent Advisor software and to investigate guidance concepts for a new flight management system. Technicians equipped the aircraft with air data and navigation systems that measured the aircraft's location and flight condition to accuracies not possible with current air traffic control radars. All participants, including airport flight controllers, the FAA, airport management, and NASA were enthusiastic about the system and the test results. Investigators performed the CTAS flight tests under a joint research and development effort involving the FAA, NASA's ARC and LaRC, the National Center for Atmospheric Research, several aerospace contractors, and United Airlines.

The FAA required the Traffic alert and Collision Avoidance System (TCAS) I, a low-power system that provides alerting and unrecommended escape maneuvers, in turbine-powered commercial airplanes with 10 to 30 passenger seats by the end of 1995. Public Law 100–236 already required that all air carrier aircraft with more than 30 passengers seats, operating in U.S. airspace, be equipped with TCAS II. TCAS II alerts the pilots to traffic and advises whether to climb or descend when a potential conflict occurs; pilots have reported that the system has already prevented midair collisions. In FY 1995, the FAA continued to monitor the technical and operational performance of TCAS I and TCAS II and to make adjustments as necessary.

The FAA's Terminal Area Surveillance System program provided a single-system replacement for the current mix of multiple aircraft and weather terminal surveillance systems. In FY 1995, that program conducted research on, and technology demonstrations of, design concepts expected to provide enhanced capabilities to increase capacity, efficiency, and safety. Focus areas included seamless surveillance, timely hazardous weather prediction and detection, and full-volume coverage while providing for lower maintenance costs and accommodating site-specific needs. The FAA also completed a cost-benefit analysis of alternative concepts and began cost-performance trades and simulations for an S/C-band single-array radar design. In addition, the FAA began an evaluation of Russian phased-array technology and U.S. computer hardware/software technology and began trade studies on a radar for low- and medium-density airports.

During FY 1995, FAA personnel expanded the Tower Data Link Service to a total of 57 airports. Demonstrations of Graphical Weather Services and Traffic Information Services begun in 1995 are to lead to a regional evaluation program and then national implementation. FAA personnel also demonstrated Terminal Weather Information for Pilots at six sites. In addition, FAA managers defined the requirements for the Initial Terminal Data Link and authorized the development of software. The development of the Key Site in the Gulf of Mexico to support Automatic Dependent Surveillance–Broadcast (ADS-B) using GPS Squitter signals continued as well. FAA personnel also worked toward the development of U.S. and international standards for controller/pilot data link communications to standardize interfaces for digital messages for air traffic communications services, helping to relieve pilot and controller workload while reducing voice channel congestion. In addition, the FAA supported the development of the context management applications, which enable aircraft and ground systems to maintain up-to-date addressing information while an aircraft is in flight.

During the fiscal year, the FAA began end-to-end testing of the prototype oceanic data link by testing an air traffic services interfacility data communications system as a prototype for ground-to-ground data link communications between adjacent Flight Information Regions. Additionally, the Department of Air Transport for the Russian Federation agreed to permit the FAA to install a prototype air traffic services interfacility data communications system in the Russian far east and connect it to the Anchorage Air Route Traffic Control Center. The FAA also participated in the development of dynamic aircraft route planning capability in the South Pacific for the rerouting of aircraft in midflight.

During FY 1995, the FAA Technical Center in Atlantic City provided national airspace simulation capability support for developing operational procedures for the New York Air Route Traffic Control Center. This is to accommodate the anticipated change from a 2,000-foot to a 1,000-foot vertical separation standard in the North Atlantic Minimum Navigation Performance Specification airspace. Air traffic controllers are faced with the problem of positioning aircraft between portions of airspace in which various vertical separation minima apply, coupled by the lack of radar coverage in the transition areas.

The FAA Technical Center also assisted in validating procedures for the use of TCAS as an aid in ensuring adequate separation between a pair of same-route oceanic aircraft at different altitudes to allow the trailing aircraft, at a lower altitude than the leading aircraft, to climb to an altitude above the leading aircraft with less along-track separation than normally required under International Civil Aviation Organization procedures.

During FY 1995, the FAA Technical Center and the Integrated Product Team for Aircraft and Avionics determined whether the display of both indicated air speed and ground speed for a leading aircraft is needed by the crew of a trailing aircraft to maintain station during an instrument approach. This study supported the FAA initiative regarding pilot situational awareness when operating in a station-keeping mode during final approach. These supported the Minimum Aviation System Performance Standards for ADS-B technology, which provides position and air speed information to the trailing aircraft.

In addition, the FAA Technical Center National Simulation Capability worked toward defining and developing a common set of air traffic communication protocols and standards and a highly reliable network architecture to support large-scale human in-the-loop simulations. DoD assisted in defining an Air Traffic Control Simulation Protocol.

Weather-Related Aeronautical Activities

In the area of weather services, personnel from the FAA continued to develop the Integrated Terminal Weather System (ITWS) to provide short-range forecast and warning notices for pilots and air traffic controllers. The ITWS prototype tests at the Orlando and Memphis airports continued, and a new test location at Dallas/Fort Worth went into operation. As a result of the prototype successes, the FAA made a decision to proceed with the full-scale development of an operational ITWS. Under its weather research initiative, the FAA combined resources with NOAA to award a contract for the development of a water vapor sensing system. United Parcel Services, Inc., agreed to have its aircraft carry these sensors and downlink the data for use in computer weather forecasting. Scientists expect that frequent observations of water vapor aloft will enable them to make significant advances in icing and storm forecasting. In FY 1995, in cooperation with NOAA's Forecast System Laboratory, FAA personnel conducted an operational evaluation of an in-flight icing forecast tool at the Aviation Weather Center. In addition, scientists from the National Center for Atmospheric Research conducted a field evaluation of ground de-icing and a snowfall computer tool at the Denver airport. The advances achieved by these investigators were transferred to industry via a series of cooperative research and development agreements.

In the area of icing, FAA personnel completed a report summarizing the latest research on icing conditions in freezing drizzle. The report recommended interim test conditions for evaluating the susceptibility of aircraft to icing in freezing rain and drizzle. In cooperation with NASA, FAA engineers continued to develop techniques for recognizing susceptibility to ice-induced tailplane stalls during icing certification testing, as well as simulation and analytical techniques from which to design and test ice-protection systems. FAA personnel began work on a new update of the *Aircraft Icing Handbook*, adding new information on the hazards of flight in large supercooled droplets. FAA researchers continued their investigation of technologies for ground de-icing and anti-icing fluids, their optimal application procedures, holdover-time guidelines, and associated aerodynamic effects. FAA personnel also undertook research, development, and evaluation of surface ice detectors and related technologies. As part of a cooperative effort with United Airlines, FAA scientists evaluated a surface ice detector system.

FAA managers commissioned Terminal Doppler Weather Radar systems in Denver, Memphis, St. Louis, and Kansas City, Kansas, during FY 1995. These systems provide for the timely detection of hazardous windshear in and near airport terminal approach and departure corridors and report that information to pilots and controllers.

During FY 1995, FAA managers also renewed the lease of the Meteorologist Weather Processor, with an option to continue the lease until the future deployment of the replacement Weather and Radar Processor system. This technology refreshment was necessary to accommodate the GOES-8 and GOES-9 weather satellites, changes to the National Weather Service communications, and a variety of format changes made to weather products that the FAA receives.

FAA personnel implemented a Wake Vortex program, which includes a joint effort with their NASA and industry colleagues to obtain site-specific capacity gains through procedural changes in sensor evaluation. Engineers completed the development of the Wake Vortex Training Aid, which addresses vortex issues from the viewpoint of both the pilot and air traffic controller, and distributed several thousand copies to the FAA and industry. In concert with DoT's Volpe National Transportation System Center in Cambridge, Massachusetts, FAA personnel established an automated Ground Wind Vortex Sensing System at Kennedy Airport in New York to monitor vortex translation in varying meteorological conditions and to evaluate new vortex detection sensors. Technicians completed testing with correlated vortex detection of a radar-acoustic sensor using that system. FAA specialists also worked closely with British officials to analyze valuable aircraft separation data from Heathrow Airport in London. The British reporting system has become a model for a proposed reporting system in the United States to provide a more useful data base of vortex encounters.

In an attempt to counter increasing congestion and delays at major airports, NASA managers initiated the Terminal Area Productivity program with the goal of safely and affordably achieving clear-weather capacity in instrument weather conditions. To determine safe aircraft separation standards, NASA researchers conducted numerous tests and investigations, such as an effort to identify and mathematically model wake vortices. In June 1995, scientists and engineers at LaRC validated a two-dimensional wake vortex model, which provided a theoretical basis for determining the proper spacing between aircraft during their approach to an airport to avoid the wake vortex produced by preceding aircraft. In another development, NASA personnel defined the concept for a new computer system to assist flight controllers, called the Aircraft Vortex Spacing System. To enhance flight operations and safety of aircraft on the ground, flight crew members used ARC's 747-400 full-mission simulator to evaluate their ability to navigate during ground taxi operations under various visibility conditions. In addition, the flight crews evaluated a three-dimensional auditory display system for ground operations, which embodied a computer-generated voice that provided verbal warnings of impending collisions with other aircraft or vehicles. Each of the 12 flight crews strongly affirmed that the auditory alert feature should be included in any future ground navigation system.

Flight Safety and Security

During FY 1995, engineers from the FAA worked to find acceptable fire extinguishing systems without halon, because the production of halon agents was outlawed in environmental regulations. FAA personnel also produced an interagency task force report for halon alternatives. In addition, FAA technicians completed testing of seat cushion fire blocking layers and developed a fire test method for airliner blankets. The tests showed that these materials, used by U.S. carriers, retain their fire resistance after service usage and remain compliant with FAA standards, but that some blankets have poor ignition resistance. In addition, FAA specialists conducted tests related to fire-hardening materials to delay fuselage burnthrough by a postcrash fuel fire. Finally, the FAA-sponsored International Materials Fire Test Working Group drafted an upgraded *Aircraft*

Material Fire Test Handbook.

In FY 1995, FAA personnel continued to address the flight safety issues raised by incorporating advanced digital systems software into aircraft and avionics systems design. Together with their NASA colleagues, FAA researchers initiated projects to assess software requirements for flight-critical applications (such as fly-by-wire, fly-by-light, and power-by-wire) and integrated modular avionics systems that use software partitioning to protect separate applications from corrupting one another.

In the area of airport visual guidance, FAA specialists completed a study for improving taxiway holding position lights and developed new performance standards. The FAA also issued final reports on improved pavement marking materials and the use of retro-reflective beads in airport pavement marking.

During FY 1995, researchers from the FAA's Airport Pavement Research program worked on developing advanced pavement design methodologies. In a related matter, the FAA issued an RFP to design and build the first national airport pavement test facility. Using planes of various sizes and tire configurations, FAA specialists completed the calibration of a complex system of almost 500 sensors that are being used to collect data in a real-time mode, providing the first means of obtaining accurate information on pavement response and performance. FAA personnel established a data base to allow airport pavement researchers worldwide to have access to the data collected. FAA engineers introduced the layered elastic design method that provided alternate pavement design guidelines for the Boeing 777's impact on airport pavement, prior to the plane's first commercial flight in 1995. FAA researchers also conducted a study of airport runway roughness profiles at 10 airports.

In materials research, the FAA published a program plan for aircraft advanced materials research and development, which was coordinated with similar findings of the National Research Council (part of the National Academy of Sciences). FAA personnel continued to work with DoD personnel on regulatory issues related to the certification and standardization of composite components. FAA researchers completed a preliminary evaluation of probability-based approaches to composite structural design, developed a preliminary data base on service-related damage incidents in composite aircraft currently in service, and conducted a case study on the application of probabilistic approaches to an existing all-composite aircraft for risk-of-failure evaluation. FAA engineers continued to analyze aircraft structural safety through the use of the crash impact facility at NASA's LaRC. Internationally, FAA specialists participated in developing an air accident investigation tool with the Civil Aviation Authority in England.

In cooperation with NASA, the FAA sponsored an international Conference on Continued Airworthiness of Aircraft Structures in Atlantic City, NJ. The two agencies also conducted numerous technical workshops on structural integrity, corrosion, and inspection research. Engineers and scientists developed a computationally efficient and accurate numerical technique, called the finite element alternating method, to predict crack linkup and residual strength in the presence of widespread fatigue damage. During the fiscal year, technicians tested two full-scale wide-body panels to provide correlation data for predictive models. Software experts developed a phase I repair design and assessment software tool and sent it to selected users for prerelease field testing.

In response to structural failures caused by aging, researchers from the FAA's Aging Aircraft program built on NASA's extensive research base in nondestructive evaluation methods, metal fatigue, and modeling for structural life prediction. The program has been moving from the technology development stage into the demonstration, validation, and technology transfer stage. Researchers have developed a wide range of prototype nondestructive evaluation instrumentation to detect the presence of corrosion and small fatigue cracks in aircraft structures and components. NASA researchers developed a prototype eddy current instrument for detecting small fatigue cracks and turned it over to a private instrument manufacturer for commercial marketing.

During the fiscal year, researchers developed a laboratory prototype of a pulsed eddy current device for corrosion detection on a Gulfstream Aero Commander wing spar. Technicians reviewed a field prototype, based on the self-compensating ultrasonic device, for possible specification as an alternate inspection technique for the DC-9 wing box T-cap. Specialists also demonstrated a pulse-echo thermal wave inspection in the laboratory and during field trials at Northwest Airlines and as part of an Air Force corrosion detection program. Aviation technicians also developed an automated aircraft wheel inspection system to classify inspection signals during automated eddy current wheel inspections.

Personnel from the FAA Technical Center continued their development of an unleaded aviation gasoline for use in the existing fleet of general aviation aircraft with piston engines. During FY 1995, a Coordinating Research Council was formed to develop the data sets required to justify changes in aviation gasoline fuel specifications. While developing the basic procedure, FAA Technical Center personnel conducted testing on an engine that is considered the worst-case scenario for knock. Technical Center specialists also provided ongoing support for autogas supplemental-type certificates and turbine fuel specification changes to the various certification offices. Most of the effort in this area is in response to changes mandated by Congress or EPA. The construction of the Fuel Research Laboratory and Small Engine Test Facility expansion began in FY 1995.

FAA researchers continued to develop technologies and methodologies to mitigate and prevent the threat of catastrophic aircraft failure. They conducted studies and tests in flight-control technologies, lightweight material barriers for high-energy rotor fragment mitigation, and aircraft loads. Grant and small business innovation research awards further expanded research in aircraft control, load technology, and rotor fragment mitigation. In FY 1995, FAA specialists completed tests to aid in the design and evaluation of a high-temperature containment ring for application on small turbine rotors. Researchers continued their work on modern analytic methods that can predict horizontal stabilizer design antisymmetric buffet loads during the airplane design phase.

The Marine Corps continued to pursue the Integrated Maintenance Diagnostics system to monitor the health of helicopter dynamic flight components. This system continued its development and evaluation in the Marine Corps CH-53E for its application in all Marine rotorcraft. Military aviation specialists have designed that system to reduce avionics repairs and prevent structural fatigue, among other preventive maintenance measures.

In the area of aviation security technology, FAA specialists certified the first explosive detection system for finding bulk explosives in checked baggage. Experts at the FAA Technical Center used the certification standard, developed by the National Academy of Sciences, to do the testing. With support from industry and the national laboratories, Technical Center personnel developed a protocol for certification testing of trace explosive detection systems. Specialists from the FAA's aircraft-hardening program completed the development and testing of prototype hardened baggage containers. The FAA awarded a grant to the Great Lakes Composite Consortium to build a limited quantity of hardened composite containers in accordance with FAA specifications. In FY 1995, FAA specialists developed a computer-based training system for x-ray screeners to improve the detection of improvised explosive devices and weapons. FAA grantees at Embry Riddle Aeronautical University developed a screener selection test to determine whether trained security applicants are capable of reaching a required level of performance. Through cooperation with industry, FAA specialists simulated the development of an x-ray false-image projection system to increase screener vigilance. During the fiscal year, FAA technicians joined with industry specialists to conduct a study of domestic passenger baggage matching.

Aviation Medicine and Human Factors

During FY 1995, personnel from the FAA continued their efforts to improve human performance in the national airspace system through research and development. FAA engineers developed a prototype automated performance measurement system to provide objective measures of crew and aircraft performance. They also enhanced a tool for systematic air traffic operations research by providing machine-based measures of the factors affecting the workload/taskload of controllers. FAA personnel developed a prototype version and began to evaluate it in the TRACON environment. FAA engineers developed a model advanced qualification program for regional airline operations, enhancing aircrew safety and efficiency, as well as a prototype computer-aided debriefing station for crew performance review following line-oriented flight training simulations. The FAA also acquired an advanced general aviation simulator to support a program of research on general aviation human factors.

Also during the fiscal year, the FAA produced a *Human Factors Guide for Aviation Maintenance*, which provided maintenance managers with established principles of job design and work in a form suitable for day-to-day reference use. FAA personnel implemented an FAA Aircraft Certification Human Factors and Operations Checklist for standalone GPS receivers. FAA researchers joined with their colleagues from NASA and industry to investigate data-link technology to solve the problems of frequency congestion and voice communication errors; the researchers identified impacts on transmission time, formats, and procedures. FAA personnel continued their efforts in an interagency study on the effects of shiftwork and fatigue on job performance.

The FAA sponsored numerous air traffic control and airway facilities human factors projects at its Technical Center. Projects included research on controller memory enhancement involving simulation research in the Human Factors Laboratory. Researchers made progress on controller-performance measurement and controller-selection tools. FAA technicians conducted airway facilities projects, includ-ng extensive prototyping for operations control center designs and the development of standards as a resource for future system design work. Finally, FAA security personnel nitiated research on security human factors to evaluate such factors as alternative baggage screener training systems.

The FAA acquired a Boeing 747, which was being retired from flight service, for integration into the aircraft cabin evacuation research program. Researchers used data from window exit cabin evacuation studies to substantiate FAA decisions about exit pathway widths. Dynamic impact studies provided information for decisions on child safety and restraint systems, as well as side-facing seat-restraint designs. The FAA initiated a joint study with the National Institute of Occupational Safety and Health on aircraft cabin environmental conditions, particularly cosmic radiation exposure and cabin air quality.

STUDIES OF THE PLANET EARTH

Terrestrial Studies and Applications

During FY 1995, NASA continued to demonstrate new techniques for observing the environment from space. The Space Radar Laboratory, which flew on the Space Shuttle *Endeavour* for the second time in October 1994 was the most technologically advanced civilian Synthetic Aperture Radar (SAR) ever flown in space. This was an international project, with the X-band SAR fabricated by Germany and Italy and the Shuttle Imaging Radar-C produced by the United States. Scientists expressed excitement about SAR's ability to measure and monitor changes on the Earth's surface, such as biomass, soil moisture, and the free water content of snow. Using interferometry, SAR scientists demonstrated that they could measure the topographic surface of Earth and detect changes as small as a few centimeters.

During the winter of 1994–95, NASA and the Canadian government continued to conduct a campaign known as the Boreal Ecosystem–Atmosphere Study—a large-scale, ground-based, and remote-sensing investigation of how forests and the atmosphere exchange energy, heat, water, carbon dioxide, and other trace gases. Observations seem to confirm that although much of the boreal ecosystem consists of wetlands, lakes, and water-logged peat beds, on which most of the forest grows, the atmosphere above the forests is extremely dry—in short, the boreal forest functions like a green desert. These data continue to correct previous weather models that overpredicted atmospheric moisture.

The Landsat series of spacecraft have provided regular observations of the Earth's surface for two decades, monitoring renewable and nonrenewable resources. Landsat data applications support programs such as global change research, coastal zone monitoring, timber management, regional planning, and environmental monitoring. More specifically, data from the Landsat-5 satellite continued to prove valuable in FY 1995 in numerous practical applications, including forest management; wheat yield, fisheries, and water resource development; earthquake and flood damage assessments; ecological, glaciological, hydrologic, and agricultural research; and geological explorations. Landsat's commercial potential was demonstrated by efforts to fight louse infestation damage to California grape vineyards; to design a complex geographic data base to access fire hazard assessment, pollution runoff analysis, and power demand prediction in the San Francisco Bay area; to identify specific crop types and to assess crop health and potential yield in Finney County, Kansas; to identify areas of rapid Chesapeake marsh loss where remediation efforts may have effect; and to help timber companies design and implement long-range sustainable forest management.

NASA also has completed significant steps in the development of the next Landsat spacecraft, Landsat-7. NASA and NOAA are to develop the ground system, which NOAA will operate. The U.S. Geological Survey (USGS) will continue to be responsible for maintaining the Government's archive of Landsat and other land-related remote-sensing data. As of the end of FY 1995, Landsat-7 was planned for launch in mid-1998.

NASA also utilized airborne tools to alleviate specific daily terrestrial problems, such as forest fires. In July 1995, for example, a NASA research aircraft played a critical role in fighting a major fire that threatened life and property in the Scottsdale and Fountain Hills areas of Arizona. The plane, a

C-130B carrying Earth-observing instruments, was diverted to the Scottsdale area to assist with combating the fire. The instruments provided critical, real-time information that was invaluable for deploying limited resources more accurately and safely to protect threatened life and property.

All of these efforts, as well as others of a more subtle nature, to observe the atmosphere and oceans, comprise NASA's Mission to Planet Earth (MTPE). MTPE provides the global perspective that is available only from space to better understand how the parts of the Earth's environment—air, water, and land—interact and make life possible. Phase 1 missions include a number of free-flying satellites for the study of specific global changes. MTPE's centerpiece is the Earth Observing System (EOS), a series of advanced interdisciplinary spacecraft that, as of the end of the fiscal year, were scheduled to be launched beginning in 1998. MTPE is NASA's contribution to the U.S. Global Change Research Program (USGCRP), an interagency research and observation effort designed to address the most fundamental questions regarding changes in global climate and environmental processes. MTPE is also an integral part of the International Earth Observing System (IEOS), in which satellites and instruments from the United States, Europe, Japan, and Canada are being closely coordinated to provide complementary data on various aspects of the Earth's environment.

During the spring and summer of 1995, NASA focused on a series of important reshaping exercises for MTPE and EOS, designed to chart the long-term implementation planning for the program. This process culminated in September 1995 with a strong scientific endorsement of EOS by the National Academy of Sciences' Board on Sustainable Development. That board concluded that MTPE should proceed with near-term EOS missions "without delay" and urged MTPE to continue infusing new cost-saving science and technology into later elements of the program. The board also recommended that NASA transfer responsibility for information product generation, publication, and user services to a federation of partners selected through an open competitive process. With the participation of the external research community, NASA began a study of the best approaches to implement these recommendations.

The EOS Data and Information System (EOSDIS), the MTPE data system, is a major component of the Global Change Data and Information System. The first EOSDIS Potential User Conference, held in June 1995, identified four user categories for data services: routine information on product inquiries, specific project users, discovery users, and indirect users. A key conclusion of the conference report was that although EOSDIS was designed to support the global change research community, EOSDIS potentially can support the needs of a broader range of users.

Development continued in FY 1995 on EOSDIS Version 0, the prototype processing, archive, catalog, and distribution system used by each Distributed Active Archive Center (DAAC) to provide a full suite of data and information services to the science community. Over a 3-month sample period in 1995, the DAAC's served an average of 12,900 users per month, who accounted for an average of 180,000 accesses to Version 0 services, including an average of 7,200 data requests.

The USGS Earth Resources Observation System (EROS) DAAC component of the EOSDIS distributed 3.7 terabytes of data in FY 1995. These data consisted principally of Advanced Very High Resolution Radiometer (AVHRR) 1-kilometer global and North America 10-day composites, the digital chart of the world, and digital elevation models of Japan, North America, and Africa. The EROS DAAC also distributed some Shuttle Imaging Radar-C data.

The Pathfinder program in FY 1995 focused on the further generation of data products for the entire time period of each data set, building on the initial benchmark period of April 1987 to November 1988. Pathfinder is a program developed by NASA and NOAA that focuses on processing, reprocessing, maintaining, archiving, and distributing existing Earth science and global environmental change data sets to make them more readily available and useful to researchers. Also in FY 1995, the Pathfinder program was institutionalized as a NASA program through the selection of 23 new peer-reviewed projects, solicited through a NASA Research Announcement.

Since 1992, the USGS has conducted the Global Land 1-kilometer AVHRR Pathfinder project in cooperation with NASA, NOAA, the European Space Agency, and an international network of 31 AVHRR data-reception facilities. More than 60,000 daily AVHRR observations have been collected by the network and archived at the USGS EROS Data Center's EOSDIS DAAC. A year-long time-exposed series of cloud-free vegetation index composites has been produced for the Western Hemisphere, Africa, and Europe; these data have been used to develop a baseline global land cover data set.

The USGS accelerated data production for EPA's North American Landscape Characterization project to complete production of triplicate data sets covering the conterminous United States and Mexico. A triplicate consists of three dates of Landsat Multispectral Scanner data from the 1970's, 1980's, and 1990's and a georegistered digital elevation model. USGS personnel prepared triplicate data sets for the NASA-funded Humid Tropical Forest Inventory project, which is mapping deforestation rates in the Amazon Basin, Africa, and Southeast Asia. These data can be obtained at no charge to the user from the EROS Data Center's DAAC through a World Wide Web home page for the Landsat Pathfinder program.

In April 1995, Project Earthlink, an interagency environmental education program, sought to improve the public's understanding of global environmental change through science fairs, the development of an educator's resource guide, video conferences, and workshops. Out of this effort, NASA took the lead of an interagency, long-term initiative to encourage the incorporation of Earth system science concepts into State and local education systems. In August, State teams of education policymakers and science experts gathered in regional forums, in which each State presented unique action plans for using existing resources to overcome obstacles that prevent the incorporation of Earth system science into the education system. NOAA, NASA, NSF, and EPA all made significant contributions to the Global Learning and Observations to Benefit the Environment (GLOBE) program, an interagency initiative that became operational this year. More than 1,500 teachers have been trained from across the country, and students from around the world are making daily measurements and receiving visual results of their compiled data.

Climate Change Data and Detection, a new program element of the NOAA Climate and Global Change program, emerged as a full-scale information management effort in FY 1995. It focused on enhancing five broad areas—data management support for program-specific activities, data archeology and reference data set development for a broad user community, better access to climate change data sets, detection and documentation of the quantitative character of observed climate changes and variations, and attribution of observed climate changes and variations to specific causes. The scientific advisory panel to NOAA's Climate and Global Change program added the last two areas to the overall program to help provide scientific focus for data management activities. In FY 1995, this program element supported governmental and academic researchers on 37 separate projects.

NOAA's National Geophysical Data Center (NGDC) continued to process all the scientific data recorded by Defense Meteorological Satellite Program (DMSP) satellites. During the past fiscal year, the volume of DMSP data increased from 2 to more than 5 gigabytes per day. Even so, the NGDC continued to prepare significant numbers of research-quality data sets for distribution to the user community and for the DMSP national archives.

The NGDC recently expanded its online services to allow users to conduct interdisciplinary data analysis, in addition to receiving information about satellite data. These services include a telephone dial-in bulletin board and Internet access through anonymous file transfer protocol, Gopher, and World Wide Web pages. During FY 1995, Internet access to the NGDC increased fourfold over FY 1994, with more than 100,000 megabytes of data downloaded by 263,000 users in FY 1995.

Many of the NGDC's FY 1995 users were from academia and were conducting research in meteorology, space physics, oceanography, and solid Earth geophysics. NGDC scientists undertook projects to investigate the amount of carbon emissions that result from fires of both anthropogenic and natural sources, as seen in global DMSP imagery. Preliminary results formed the basis for extended U.S.-Russian cooperation through the joint Environmental Working Group cochaired by NOAA.

In the area of hazardous waste, EPA used aerial photography to develop site-characterization data during remedial investigation and feasibility studies conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). EPA completed more than 100 aerial photographic surveys of hazardous waste sites under the CERCLA and Resource Conservation and Recovery Act (RCRA) programs. Satellite imagery played an important role in helping scientists develop detailed site characterizations.

EPA's Environmental Photographic Interpretation Center worked with the Army Corps of Engineers to analyze aerial photographs and to develop spill contingency plans for emergency crews handling oil and other hazardous materials in U.S. waterways. The center also used remote sensing to identify hazardous spills and other potential problems that might occur as a result of severe flooding or other natural disasters.

In FY 1995, the U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) used remote-sensing data to construct area frames for statistical sampling in estimating planted crop area, to create crop-specific land-cover data layers for geographic information systems (GIS), and to assess crop conditions. Products from the first two areas were based on high-resolution digital satellite data, such as the Landsat-5 Thematic Mapper (TM) and the Satellite Pour l'Observation de la Terre (SPOT) (satellite for the observation of the Earth) Multispectral Scanner (MSS) data, while crop condition assessment utilized low-resolution data from the NOAA-14 satellite.

For the first time, in FY 1995, researchers employed samples from the New York and South Carolina area frames for their studies. For area frame construction, they combined digital Landsat and SPOT data with USGS digital line graph data, enabling the user to assign each piece of land (in a State) to a category based on the percentage cultivated or used in other ways. NASS also tested the feasibility of using data from the Indian Remote Sensing (IRS-1B) satellite for area frame construction in the event of a failure to Landsat-5. This test used 1994 Linear Imaging Self-Scanning Sensor (LISS-II) data over a portion of western Kansas and found the LISS data to be an acceptable but not preferable replacement for the Landsat-5 TM.

The 1995 delta remote-sensing project in Arkansas focused on the analysis of multitemporal SPOT MSS data from the 1994 crop season and produced crop-specific digital data layers and crop acreage estimates for rice, cotton, and soybeans. This was to be the first NASS large-area and large-volume test of SPOT data. However, ground controllers redirected SPOT satellite observations away from Arkansas during the critical summer overpasses, and only a small area of summer scenes was acquired. August (single-date) Landsat-5 TM data purchased to replace the lost scenes outperformed the available multitemporal SPOT data for crop acreage classification. Another related study compared single-date LISS-II data from the IRS-1B satellite to both the SPOT MSS and TM in a small subset of the Arkansas area; TM again was best for crop acreage, with IRS LISS better than SPOT MSS. During the summer, Landsat TM and SPOT data were acquired over Arkansas to continue this project for the 1995 crop season.

NASS scientists investigated the possibility of using the new NOAA-14 AVHRR sensor by comparing biweekly vegetative index map products for the 1995 crop season to previous seasons' NOAA-11 data. Crop condition assessment map products, based on the recalibrated data, were distributed to NASS offices and USDA policymakers for the August and September Agriculture Statistics Board's reviews. In related yield research, four data sets of Landsat-5 TM imagery were obtained for a spring wheat area on the border of North and South Dakota. The combined dates were used to create a crop-specific classification. Landsat-5 TM vegetative indices will be calculated for spring wheat areas only and compared via the yield models to AVHRR indices, based on multiple-cover types.

Scientists at the Beltsville, MD, Remote Sensing Research Laboratory and other USDA Agricultural Research Service (ARS) locations conducted research and developed applications for "precision agriculture." This required implementing an equipment and information system using tools such as remote sensing, GIS, and GPS instruments, which allow farmers to make field-specific decisions for economic and environmental control. A widening array of equipment has been developed to use GPS and machine-adapted computer mapping to differentially apply chemicals, fertilizers, and various seeding rates and densities.

The incentives to adjust management, at a fine grid level within a production field, are improving production efficiency, protecting the long-term production environment, or both. Examples of some of the remote-sensing techniques that have been developed by ARS scientists include (1) designing a tractor-mounted sensor to provide on-the-go soil testing for nitrogen fertilizer, (2) developing a near-infrared-reflectance sensor to measure soil organic matter and moisture important to the utilization of fertilizer and soil applied herbicides, and (3) using electromagnetic induction sensing to measure the topsoil depth on claypans, allowing for adjustments to be made in fertilizer application for effective crop use.

A variety of remotely sensed means was used to identify plant stress and soil conditions and, in general, relate vegetation to other measured variables, including gridded yield data, at the time of harvest. Geostatistical methods were employed not only to quantify the variability found within crop fields but also to develop strategies for sampling plant data to adequately represent and characterize field measurements.

The ARS facility in Weslaco, TX, completed a study of saltcedar (*Tamarix chinensis*) infestations in the southwestern United States using spatial information technologies such as airborne video data, GPS, and GIS. The study focused on areas along the Colorado River in Arizona and the Rio Grande and Pecos Rivers in Texas. In November 1994, saltcedar infestations were distinguished readily on conventional color video imagery when foliage turned a yellow-orange to orange-brown color prior to leaf drop. The integration of GPS with video imagery permitted latitude-longitude coordinates of saltcedar infestations to be recorded on each image. These coordinates were entered into a GIS to map saltcedar populations along the three river systems.

Weslaco scientists also produced a vegetation community map of the Santa Ana National Wildlife Refuge, near Alamo, TX, in cooperation with refuge personnel. The baseline information provided on the map assists refuge managers in monitoring changes and determining the habitat requirements of various wildlife species, such as the endangered ocelot.

In Phoenix, AZ, ARS Water Conservation Laboratory (WCL) scientists completed the multispectral airborne demonstration, a 6-month experiment at the Maricopa Agricultural Center. By acquiring biweekly airborne images of an 800-hectare farm in Arizona, along with intensive ground-based measurements, WCL scientists investigated the real-time use of remote sensing for farm management. These biweekly measurements were combined with a crop simulation model and will be used to develop the techniques necessary to provide daily crop and soil information to the farm manager for making management decisions.

WCL scientists collaborated with engineers at the Sandia National Laboratory in Albuquerque, New Mexico, to explore agricultural applications of airborne sensors initially developed for military use. Based on optical and microwave images provided by Sandia engineers, WCL scientists found that this combination of spectral data could provide valuable information about both crop growth and soil moisture.

In addition, WCL scientists developed a water deficit index to assess the water status of a crop and help determine water needs. This is important, particularly for producers located in arid and semi-arid areas of the world who are almost totally dependent on irrigation. The index represents a breakthrough in irrigation scheduling because agronomists can apply it to both sparse and dense vegetation, and it requires few input parameters other than remotely-sensed data.

Also in FY 1995, WCL scientists took the first steps toward optimizing the use of multiple sensors on multiple dates for evaluating of crop conditions and water loss from agricultural areas. Working to enhance the usefulness of such imagery, WCL scientists developed an operational method of normalizing the effects of viewing angle on spectral response and then inverted this process to use bidirectional measurements as a source of information about crop stress and structure.

Scientists at the ARS Hydrology Laboratory in Beltsville, MD, developed improved snowpack microwave remote-sensing algorithms through the use of electron microscope imaging of snow crystal size, shape, and structures. At the Jornada Experimental Range in New Mexico, scientists began multilevel, multisensor remote-sensing work directed at measuring evaporative fluxes and characterizing areal vegetation changes in arid rangelands.

New remote-sensing procedures, developed by ARS at Weslaco for determining the effects of soil salinity on sugarcane and cotton, were applied in 1994 as a pilot test to the 20,000 hectares of irrigated wheat in the El Carrizo Irrigation District near Los Mochis. Both salinity and yield maps were produced that correlated well with crop performance. Users there were able to apply the procedures in 1995 to the 200,000-hectare Yaqui Irrigation District that surrounds Ciudad Obregon.

The USDA Forest Service, under an agreement with the USGS National Mapping Division, assumed responsibility for revisions to maps covering National Forest System lands. Aerial photography and satellite imagery have provided the primary sources of data for maintaining more than 10,000 topographic quadrangle maps and associated derived map products. These maps are essential for Forest Service resource management activities and are also available for sale to the general public.

In FY 1995, remote-sensing data supported a wide variety of ecosystem management activities, including wildfire detection and suppression, vegetation classification, resource change detection, land management planning, damage assessment following natural disasters, the identification of critical wildlife habitat, support to law enforcement, and inventory programs. The Forest Service used a wide variety of remote-sensing platforms, from AVHRR for wide-area coverage to Landsat TM and SPOT for higher resolution imagery.

Research and development of airborne video, digital camera systems, radar, and GPS navigation continued to meet the needs of diverse ecosystem management applications. As the Forest Service moved to implement a national GIS, remotely sensed data continued to provide an integrated information base over wide areas.

The remote-sensing program of the USDA Foreign Agricultural Service (FAS) continued to be a critical element in the analysis of domestic and foreign agricultural production by providing timely, accurate, and unbiased estimates of global area, yield, and production. The agency used satellite imagery, crop models, and remotely-sensed weather data to support DoS assessments of food needs in the states of the former Soviet Union, particularly Russia. FAS also prepared detailed analyses of droughts in northern Mexico, Argentina, and southern Africa and used satellite imagery to assess domestic crop conditions in support of work carried out by the Consolidated Farm Service Agency.

The USDA Natural Resources Conservation Service (NRCS) shared costs with other Federal and State agencies to acquire aerial photography through the National Aerial Photography Program (NAPP) and produced digital orthoimagery. NAPP is being used as source imagery to develop digital orthoimagery to support the NRCS soil survey program, conservation technical assistance to private land users and GIS implementation. Digital orthoimagery combines the image characteristics of an aerial photograph with the accuracy and scale associated with a map. Technicians achieve these desirable imagery qualities by removing displacements caused by camera tilt and terrain relief. NRCS is a member of the interagency National Digital Orthophoto Program. Four Federal agencies and selected State agencies contributed funds to this program for the development of 1-meter resolution digital orthophotos. The NAPP imagery and digital orthoimagery are acquired by contracting to the private sector. As of October 1, 1995, about 20 percent of the conterminous United States was either complete or in progress.

DoI continued to cooperate with DoD to use the Navstar GPS Precise Positioning Service (PPS). By accessing the encrypted DoD GPS code, DoI users obtain more accurate, real-time, on-the-ground geographic location information (approximately 10 meters horizontal accuracy) than is currently available nationally using other GPS technology. DoI's Minerals Management Service used GPS in Federal offshore waters to determine the positions of occupied and abandoned oil and gas platforms, wellheads, and pipelines. They also used GPS to obtain accurate positions for mineral resources, protected wildlife species, and archeological artifacts. DoI's Office of Surface Mining Reclamation and Enforcement expanded its use of Navstar GPS to locate water and mine overburden sampling sites for the Appalachian Clean Streams Initiative. This multi-agency effort is a public-private partnership aimed at predicting, preventing, and mitigating acid drainage from abandoned coal mines. DoI also has used Navstar GPS in the reclamation of remote mines in the White River National Forest of Colorado. The USGS also used GPS to map natural resources and geologic hazards. Access to Navstar GPS PPS is especially beneficial in remote locations where differential corrections are difficult to make and where accurate positions are required to relate observed phenomena to geologic features and hydrologic conditions. For example, USGS personnel used GPS techniques to map boundaries of potentially lethal quantities of carbon dioxide gas emanating from Mammoth Mountain in California after snow melted.

DoI's Bureau of Indian Affairs (BIA) used remotely-sensed data and GPS to conduct natural resource inventories, image mapping projects, GIS data base development, and training to support the BIA Indian Integrated Resource Information Program. BIA staff used Landsat-5 TM data to classify land cover on several reservations for agricultural assessment and forestry and wildlife applications. Land cover mapping continued in New Mexico and Colorado to provide input for modeling potential burn rates of varying vegetation types in response to fires. BIA staff also prepared image maps for more than 15 reservations using data from the Landsat TM and SPOT. BIA staff who produce GIS data bases that support resource inventory programs took GPS training during FY 1995.

DoI's Bureau of Land Management continued to use remotely-sensed data and GPS technology to monitor the health of public lands and in all aspects of its ecosystem-based management activities, including inventory, assessment, modeling, and monitoring. The analysis of aerial photographs and satellite data directly supported the ecosystem-based management of mineral resources, land use planning, fire fuels mapping, the characterization of wildlife habitat, and the delineation of hazardous material impacts at a number of sites on public lands throughout the United States.

DoI's Bureau of Mines continued to apply remote-sensing to studies of abandoned noncoal mine lands in the Cripple Creek mining district in central Colorado. Data from the Landsat TM and NASA's Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) provided valuable new information about the associations among clay minerals, iron minerals, and sulfides, in addition to their relationship with acid potential of mine wastes. The use of remote-sensing analysis to guide sample collection for chemical testing significantly reduced the time and cost of site prioritization and evaluation by land managers and regulators at the Federal, State, and local levels.

DoI's Bureau of Reclamation used remote sensing and GIS to aid in the management of water resources. During FY 1995, it used Landsat-5 TM and SPOT data to map irrigated lands, riparian vegetation, and open water in the Colorado River Basin. Together with other spatial data and environmental models, scientists used these maps in a GIS to produce estimates of consumptive water use. Reclamation staff used aerial photographs to prepare large-scale maps of land cover for environmental impact statements and water use models. They also used airborne video and thermal infrared scanner imagery to map river habitat for endangered fish species in the Colorado River system, including the Colorado River in the Grand Canyon. These maps help reservoir managers regulate water flow to encourage the survival of endangered fish.

The U.S. Fish and Wildlife Service (FWS) continued to use computerized mapping, aerial photography, and satellite data to support ecosystems management and data-sharing initiatives with Federal, State, and local agencies and private industry. For example, its national wetlands inventory used high-altitude aerial photographs to produce wetlands maps of more than 80 percent of the United States and its territories. More than 16,000 digitized maps are available through the World Wide Web; in its first year, individuals and agencies from the United States and 25 other countries downloaded more than 93,000 maps. The national wetlands inventory and a private company developed a procedure, now patented by that company, to compare digital wetlands maps with later-date Landsat TM data to automatically determine whether a single wetlands map is still current or requires updating.

The National Biological Service (NBS), in partnership with FWS, continued to use Landsat TM and SPOT data in the Gap Analysis Program for identifying biological resources on lands that are not adequately protected to preserve biological diversity. These projects are funded in 40 states, involving hundreds of cooperating organizations at the Federal, State, and local levels. Scientists and technicians completed or nearly completed vegetation mapping in Arkansas, Arizona, California, New Mexico, Nevada, Utah, Washington, and Wyoming.

NBS used Landsat TM and AVHRR data to forecast the annual production of Arctic nesting geese and to study winter waterfowl habitats in the Central Valley of California. NBS personnel also used AVHRR data to identify damage in forested wetlands caused by Hurricane Andrew in Louisiana. Scientists also investigated the use of satellite radar imaging to estimate the amount and type of fire fuels, to detect flooding beneath marsh canopies, and to determine marsh impacts. NBS has been participating on an EOS interdisciplinary team investigating the use of NASA's AVIRIS data to estimate snow grain size, surface albedo, and liquid water content in the surface snow layer in California's Sierra Nevada Mountains. NBS also used GPS for locating field sampling points, establishing precise control points for photogrammetric applications, studying river bathymetrics/profiles and desert tortoise habitat, mapping prairie dog towns, recording ranges and locations of rare and endangered plants, and determining spread rates of exotic species.

The National Park Service (NPS) continued to work with NBS to conduct a comprehensive, multiyear vegetation mapping program in more than 235 units of the National Park System to support the NPS inventory and monitoring program. Scientists initiated prototype mapping projects in five parks, representing a variety of ecoregions to test the National Vegetation Classification System and mapping protocols developed during the first year of the program. NPS and NBS also worked together using GPS to map and monitor shoreline changes in large coastal NPS units, such as the Cape Cod, Fire Island, and Assateague Island National Seashores and the Gateway National Recreation Area, especially during the fall storm season when significant shoreline changes occur.

NPS used Landsat-5 TM data to complete land-cover mapping in Alaska for Cape Krusenstern National Monument, Yukon-Charley Rivers National Preserve, and Kobuk Valley National Park. The Landsat system operator moved a portable Landsat receiving station to Fairbanks at the end of the 1995 summer season to acquire more complete Landsat coverage of Alaska. However, the timing of the station setup and unfavorable weather conditions resulted in little data collection for the 1995 growing season. NPS requested that the station be left in place for additional seasons. NPS used SPOT satellite data for the management and planning of the new Mojave Desert Preserve in California, particularly for detecting surface disturbances, developing trails, and studying recreational vehicle use.

The Multi-Resolution Land Characteristics Monitoring System, developed jointly by the USGS, EPA, NOAA, and other DoI partners, has contributed data to several projects, including weather forecasting, fire danger modeling, and ecoregions mapping. The USGS and the University of Nebraska at Lincoln have been developing an associated global land-cover characteristics data set with 1-kilometer AVHRR data.

By Executive Order of the President in February 1995, the Government declassified imagery acquired by intelligence satellites in the 1960's, thus extending the record of openly available remotely sensed data of the Earth's land surface back by a decade before the first Landsat satellite. The National Archives and Record Administration is to make this imagery available, while the USGS EROS Data Center will provide a catalog of the entire collection and a limited number of images through its online electronic Global Land Information System.

Atmospheric Studies and Applications

A significant highlight of FY 1995 was conclusive results regarding the Antarctic "ozone hole." Several years of data from satellites and aircraft had provided proof that human-produced chemicals comprised at least 80 percent of the chlorine in the stratosphere causing Antarctic ozone depletion. Ozone, a molecule made up of three atoms of oxygen, forms a thin layer of the atmosphere that absorbs harmful ultraviolet radiation from the Sun. The term "ozone hole" is used to describe a large area of intense ozone depletion that occurs over Antarctica during late August through early October and typically fills in late November. Ground-based measurements by NASA and NOAA indicated that lower atmospheric growth rates of major ozone-depleting substances have declined significantly in response to international efforts to reduce emissions. NASA's Upper Atmosphere Research Satellite (UARS) has provided the only global monitoring of this process.

An early highlight for FY 1995 was the third flight of NASA's ATLAS payload on the Space Shuttle. ATLAS-3 was designed to measure the variations in the solar output and its effects on the Earth's atmosphere over the course of an 11-year cycle. It successfully calibrated instruments to measure both atmospheric and solar energy. In addition, the ATLAS-3 instruments were able to measure precise levels of more than 30 chemicals in the atmosphere.

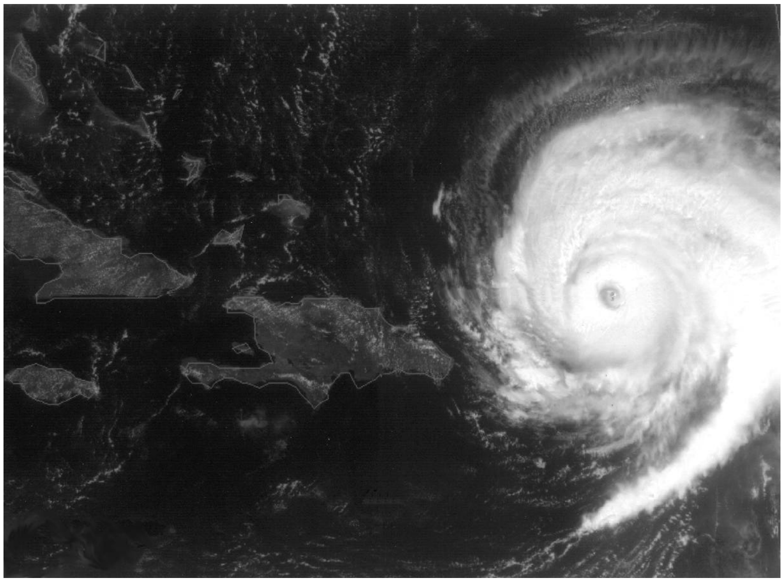
Researchers used data from a small instrument, the Optical Transient Detector (OTD), launched in April 1995 on the Microlab I commercial satellite, to identify the formation of tornadoes and severe storms from space. The OTD gave researchers a much more comprehensive view of lightning generated by severe storms than is generally available from ground observations. The OTD is the testing model of the lightning imaging sensor instrument, part of the upcoming Tropical Rainfall Measuring Mission (TRMM), a joint U.S.-Japan spacecraft.

From August to September 1995, NASA, the Brazilian Space Agency (AEB), and Brazil's National Space Research Institute conducted the Smoke/Sulfate, Clouds and Radiation Experiment–Brazil. This experiment marked the first large-scale cooperation between NASA and AEB, which was established in 1994. The experiment successfully used aircraft and ground-based sensors to study atmospheric aerosols and their influence on clouds and climate.

The GOES spacecraft series provided continuous operational environmental monitoring coverage with images and soundings during FY 1995. GOES-8, the first satellite in a new series, was moved to its final, operational position in February 1995, and on June 9, 1995, NOAA declared it fully operational. Its three-axis stabilized design allows its sensors to continuously observe Earth and thus provide more frequent views of weather systems, compared with the earlier spin-stabilized satellites that view Earth only 5 percent of the time. NASA successfully launched GOES-9, the second advanced satellite in this series, on May 23, 1995, and NOAA personnel assumed control on July 21, 1995. Upon completion of on-orbit satellite and instrument checkout in October 1995, GOES-9 was scheduled to join GOES-8 in early 1996 in providing the United States with full coverage by the most advanced weather monitoring capability. NOAA is responsible for operating GOES, including command and control, data reception, product generation, and data and product distribution. NASA manages the design, development, testing, launch, and postlaunch checkout of GOES for NOAA.

In the Polar-orbiting Operational Environmental Satellite (POES) program, NASA successfully launched the NOAA-J satellite on December 30, 1994, from Vandenberg Air Force Base, CA. This satellite, renamed NOAA-14 once it achieved orbit, assumed the role as the primary afternoon spacecraft in the POES constellation. Following the initial spacecraft checkout, NOAA-14 assumed full operational capability in June 1995. The POES spacecraft continued to provide temperature and humidity profiles for weather forecasting, imagery for cloud/frontal/snow cover analysis, warnings of tropical cyclones and volcanic eruptions, data for sea-surface temperature and ice analyses, and vegetation indices for climate and global change.

Work to define the observational requirements and satellite configuration of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) continued at the program's tri-agency (DoC, DoD, and NASA) integrated program office. The NPOESS program, which converges the military and civilian polar-orbiting operational environmental satellite programs of DoD and NOAA into a single system, proceeded successfully through its initial planning phases. The Secretaries of Commerce and Defense and the NASA Administrator signed a Memorandum of Agreement in May 1995 to implement the President's Directive of May 1994.



This Geostationary Operational Environmental Satellite (GOES-8) visible-channel image shows Hurricane Luis on September 6, 1995, as it made landfall over Puerto Rico. GOES-8 is operated by NOAA and circles the Earth in a geosynchronous orbit 22,300 miles above the Equator.

DoC, through NOAA, has lead agency responsibility for a tri-agency executive committee for NPOESS. NOAA also has lead agency responsibilities to support the integrated program office's satellite operations and to interface with national and international civil users. DoD has lead agency responsibility to support the office for NPOESS acquisitions, launch, and systems integration. NASA has lead agency responsibility to support the office in facilitating the development and incorporation of new, cost-effective technologies to enhance the capabilities of NPOESS.

Negotiations continued with key European partners—the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), with involvement as appropriate of the European Space Agency (ESA)—on a joint polar system, taking into account, on the U.S. side, the converged U.S. system. This complements long-standing plans by NOAA and EUMETSAT to exchange instrumentation for flight on meteorological operational satellites.

NOAA satellite measurements of ozone during the winter of 1994–95 indicated that the total column ozone amount was unusually low over regions of the Northern Hemisphere. For middle and high latitudes, ozone values were 10 to 20 percent lower than typical values observed during these months in 1979 and the early 1980's. Over some high-latitude regions, such as Siberia, total ozone in 1994–95 had decreased by up to 35 percent from 1979 values. Total ozone has decreased since 1979 over Northern Hemisphere midlatitudes at the rate of about 4 percent per decade. Researchers observed little or no significant long-term trend for the equatorial region. Temperatures observed over the north polar region were sufficiently low for chemical ozone destruction polar stratospheric clouds within the polar vortex during the 1994–95 winter-spring period. A stratospheric warming during February 1995 interrupted the period of record-low minimum temperatures, but record-low minimum temperatures returned in the polar region during March 1995.

Also in the area of ozone monitoring, the use of the Television and Infrared Operational Satellite (TIROS) Operational Vertical Sounder (TOVS) 9.7-micron ozone channel as a robust, real-time monitor of the ozone shield steadily gained acceptance in the ozone community. Its unique polar night capability and enhanced sensitivity to lower stratospheric ozone depletion allowed it to complement more traditional atmospheric backscattering measuring instruments.

The AVHRR Atmosphere Pathfinder project is a National Environmental Satellite, Data, and Information Service (NESDIS) (part of NOAA) activity in support of the NOAA/NASA Pathfinder program. Its objectives are to use community consensus algorithms and uniformly calibrated AVHRR data to reprocess all afternoon NOAA satellite data back to 1981 into a consistent record of atmospheric parameters for climate change studies. During FY 1995, researchers processed 1 month of data (September 1989) into cloudy and clear radiance statistics, total cloud amount, top of the atmosphere radiation budget, and aerosol optical thickness over the oceans. Scientists also began to generate data for a benchmark period spanning from March 1987 through October 1988. The output products were provided twice daily on an equal area grid with a resolution of 110 kilometers and averaged over 5-day and monthly periods. A future extension is to include multilayer cloud amount by cloud type, surface radiation budget parameters, and cloud optical properties. Also during FY 1995, NOAA scientists produced a data set of deep layer mean temperature for the period December 1986 through December 1994. Scientists used this data set, based on observations of the microwave sounding unit on NOAA's POES, to study temperature trends throughout the troposphere and lower stratosphere.

In addition, NOAA's NGDC worked with many Pathfinder groups in NASA and NOAA to bring together the "Pathfinder Climate Data Collection." This CD–ROM includes data from AVHRR and TOVS Pathfinders for the benchmark period (April 1987–December 1988). NGCD stored these data in simple formats, allowing access with many popular science software tools. This CD was expected to be available during the first half of FY 1996.

NOAA's Global Climate Perspectives System achieved a new update capability for monthly and seasonal global temperature and precipitation during FY 1995. Researchers implemented complex quality control procedures, produced gridded global products, and published numerous scientific papers.

During FY 1995, NOAA's Comprehensive Aerological Reference Data Set project completed the building of a kernel data base containing daily global upper air observations for the period 1973–1990. Scientists combined data from about 20 different sources to form this online data base. In addition, they developed and implemented a complex quality control system.

NOAA scientists continued their work on the Trace Gas Project during FY 1995. They collected global baseline trace gas data sets, such as for CO_2, CH_4, O_3, and chlorofluorocarbons, and checked the data sets for quality control. Researchers then documented, placed online, and secured the data sets in the NOAA/NCDC (National Climatic Data Center) archive.

Also during FY 1995, scientists from the U.S. Historical Climatology Network, a joint project between DoE and NOAA, prepared and quality-checked data sets of numerous climatological variables. On the global level, DoE and NOAA cooperated in the Global Historical Climatology Network for data collection and quality assurance of monthly temperature, precipitation, and pressure data.

The U.S. Precipitation Metadata Project produced data sets of monthly rainfall and snowfall during FY 1995. Researchers removed wind-induced turbulence biases by using data on such factors as gauge sitings, gauge shields, and average monthly wind speeds, as well as by developing algorithms for bias removal.

NOAA's Surface Reference Data Center supported precipitation validation within the Global Precipitation Climatology Project. The center provided support by collecting and validating precipitation station data from a number of globally distributed test-site areas. Work during FY 1995 concentrated on the production of area-averaged validation data for all test sites, with the inclusion of precipitation/elevation adjustment algorithms.

As part of the U.S. Global Change Research Program, scientists conducted numerous coordinated campaigns using lidar, radar, and all-sky optical imagery from the ground to obtain signatures of "breaking" gravity waves at mesopause altitudes. These scientists simulated wave structures by using a numerical model of breaking gravity waves. In addition, they used the characterization of the global semidiurnal tides to extend the Thermosphere-Ionosphere Mesosphere-Electrodynamics General Circulation Model to altitudes down to 30 kilometers.

The NSF has established a unique position in supporting studies of the way variations in the energy output from the Sun contribute to global change, as well as the way these results may affect conclusions related to the importance of anthropogenic effects. The Radiative Inputs from Sun to Earth program, for example, has supported photometric observation of sunspots, faculae, and other features that are sources of solar brightness variations.

In efforts to forecast space weather, scientists at Rice University developed the Magnetospheric Specification and Forecast Model, which provides short-term forecasts of particle fluxes in space. Rice scientists developed a magnetohydrodynamic model of the magnetosphere in an attempt to simulate the dynamics of a substorm. Recently, researchers have begun to identify some of the physical processes that cause substorm initiation, while other triggering mechanisms remain unexplained.

One space weather effect that does not follow the trail of energy from the Sun is equatorial scintillations, which cause serious problems in space-based communications and navigation systems, such as GPS. NSF scientists mounted a campaign in September to October 1994, near the magnetic Equator in South America, to understand the physical processes that control the triggering of equatorial irregularities, which give rise to the intense scintillations, but further study was needed before a predictive capability could be developed.

On April 3, 1995, Orbital Sciences Corporation placed a MicroLab-1 satellite in low-Earth orbit. The NSF, along with the FAA, NOAA, and NASA's Jet Propulsion Laboratory (JPL), joined with Orbital Sciences Corporation and Allen Osborne Associates to sponsor a proof-of-concept experiment using MicroLab-1 to test whether GPS radio signals can provide accurate and high-resolution three-dimensional distributions of atmospheric temperature and water vapor. The initial results for temperature profiles between 5 and 40 kilometers were excellent when compared with standard radiosondes. Beyond this range, preliminary temperatures showed difficulties. In the upper atmosphere, the errors resulted from initial temperature and pressure assumptions in this region and initial ionospheric refraction assumptions. In the lower troposphere, the errors seemed to be associated with multipath effects caused by large gradients in refractivity caused by water vapor distribution.

An instrument designed to monitor ozone levels in the Earth's atmosphere was launched from French Guiana on April 20 aboard ESA's second European Remote Sensing Satellite (ERS-2). Scientists and engineers at the Smithsonian Astrophysical Institute (SAO) developed the Global Ozone Monitoring Experiment in cooperation with European scientists to generate a complete world ozone map every 3 days.

The Polar Ozone and Aerosol Measurement (POAM-II) experiment on the Sun-synchronous SPOT-3 satellite continued to provide vertical profiles of important middle atmosphere constituents, such as aerosols, nitrogen dioxide, oxygen, ozone, and water vapor, over the polar stratosphere. Sponsored by the Naval Research Laboratory and the Ballistic Missile Defense Organization (BMDO), this experiment was launched in September 1993. POAM-II data have contributed significantly to scientific understanding of infrared laser and electromagnetic wave propagation through the polar stratosphere, as well as to understanding of the polar ozone depletion process. POAM-II also confirmed the role of the polar vortices in ozone depletion and detected the presence of polar stratospheric clouds.

Oceanographic Studies and Applications

Launched in August 1992, the joint U.S./French satellite TOPEX/Poseidon demonstrated a new way of monitoring global mean sea-level variations. The satellite used a radar altimeter to measure sea-surface height very precisely and made global observations of the sea level every 10 days. The satellite not only monitored the mean sea-level change, it also told scientists where the change occurred, allowing researchers their first opportunity to study the natural causes for short-term sea-level variations and distinguish them from broader effects. On the basis of 3 years' worth of continuous measurements, the satellite detected sea-level rise at a rate of 4 millimeters per year. This is a critical new observational capability for climate research.

A major study used new computer models and data from the 10-year Tropical Ocean Global Atmosphere-Coupled Ocean-Atmosphere Response Experiment, an international research program that studies how Earth's oceans and atmosphere affect one another to make yearly predictions of equatorial Pacific sea-surface temperatures and related changes in precipitation patterns. One of the main targets of this research has been the El Niño, a climate disturbance that occurs every 2 to 5 years in the Pacific Ocean. Recent El Niño events may have played a key role in sea-level rise over the past 3 years. This effort also has helped explain the rise in sea levels.

The NOAA Satellite Ocean Remote Sensing (NSORS) program was begun during FY 1995 and is an integrated effort involving ocean data from NOAA polar and geostationary satellites, as well as several other space-based systems—the Defense Satellite Meteorological Program, Canada's Radarsat, classified DoD data, and Japan's Advanced Earth Observing Satellite (ADEOS). NSORS involves data acquisition, algorithm development, calibration/validation, product development, product operations, user access/exploitation, and archival activities. During FY 1995, NOAA created an NSORS Implementation Plan and an Internet home page. In addition, NOAA personnel prepared hardware and communications equipment for the reception of Radarsat and ADEOS data; developed experimental ocean-surface wind products for operational customers; contracted for four instruments to be flown on NOAA aircraft for ADEOS validation; and electronically provided remapped GOES visible imagery prototype products in near real time for the U.S. east coast, Great Lakes, and Gulf of Mexico. NOAA scientists began developing new products from future ocean color sensors, nitially limiting these products to the ocean areas around the coastal waters of the United States.

During FY 1995, NOAA increased by 30 percent the number of CoastWatch applications (now approximately 250) signed with users of CoastWatch data. CoastWatch, a ong-standing NOAA program now under NSORS, uses high-resolution, near-real-time polar satellite data, covering all U.S. coastal areas, to measure sea-surface temperature and reflectance for monitoring river outflow and tracking oceanic features, including "red tide" events and locations of temperature-sensitive fisheries.

Following the launch of NOAA-14 during FY 95, NOAA defined new algorithms for the computation of global sea-surface temperature observations from the AVHRR. Researchers increased global sea-surface temperature observations by improving cloud detection in the areas of the ocean affected by glare from the Sun.

Also in the area of oceanographic studies, work continued on the multi-agency Comprehensive Ocean-Atmosphere Data Set project to provide an updated reference data set covering the world's ocean environment. Specific FY 1995 accomplishments included entering data for 3.5 million U.S. Merchant Marine observations for the 1912–1946 period and the establishment of an agreement with China to enter data for the U.S. Maury Collection, which consists of 19th century ship observations.

NASA, NOAA, and the Navy held discussions on the possible merger of the NASA/French space agency (CNES) TOPEX/Poseidon Follow-On (TPFO) mission with the second Navy Geodetic/Geophysical satellite (Geosat) mission. NASA and the Navy agreed to proceed with the NASA TPFO mission, modified to meet the Navy's tactical requirements. The Navy completed the critical design review for the Geosat Follow-On satellite in August 1995. Researchers expect this radar altimeter satellite to provide timely, worldwide, and very accurate measurements of ocean topography via direct readout to ships at sea and selected shore sites.

INTERNATIONAL AERONAUTICAL AND SPACE ACTIVITIES

Cooperation With Foreign Partners

DoS and NASA continued negotiations on the formal agreements relative to the International Space Station program. During FY 1995, DoS held five rounds of negotiations between the existing partners and Russia on the Space Station Intergovernmental Agreement. In parallel, NASA continued negotiations with the Russian Space Agency (RSA) on a bilateral memorandum of understanding, as well as with the European, Japanese, and Canadian space agencies on amendments to their respective Space Station memoranda of understanding to reflect Russian involvement in the program and modifications to respective contributions by the partners. The plan for shared design, development, operations, and utilization of the International Space Station already has provided concrete opportunities for successful international collaboration among the various governments, industries, universities, and individual scientists. The ongoing interaction with Russia on the Shuttle-*Mir* and International Space Station programs has contributed positively to the U.S. policy of encouraging Russia to continue on its course to democratization and a market economy.

The most visible symbol of U.S.-Russian scientific and technological cooperation was the first rendezvous and docking of the Space Shuttle *Atlantis* with *Mir,* which occurred on June 29, 1995. This coincided with the fifth meeting of the U.S.-Russia Commission on Economic and Technological Cooperation, known more widely as the Gore-Chernomyrdin Commission after its leaders, U.S. Vice President Al Gore and Russian Prime Minister Viktor Chernomyrdin.

Another highlight at the fifth meeting of the Gore-Chernomyrdin Commission was the new cooperation involving seven Russian aeronautics institutes and four NASA aeronautics research centers. During FY 1995, NASA signed five grants with Russian aeronautics institutes for a wide range of research, such as advanced aviation metals, atmospheric effects of aviation, and composite structure research. Joint aeronautics projects included modifying the Russian Tu-144 supersonic transport plane with new engines to flight-test new technologies for the next-generation supersonic civil transport and cooperative work on scramjet propulsion technology, a critical element in the development of hypersonic aerospace vehicles.

Under the auspices of the Scientific and Technical Committee of the Gore-Chernomyrdin Commission, NASA, the Russian Ministry of Science and Technology Policy (MinSci), and the Russian Space Agency (RSA) signed the Memorandum of Understanding on Cooperation Relating to the Space Biomedical Center for Training and Research. The Center, to be based at Moscow State University, will support a range of U.S.-Russian medical exchanges, including cross-training and research in aerospace medicine, space biology, internal medicine, public health issues, biotechnology, microgravity sciences, informatics, and telemedicine.

In April, 1995, the "Integrated Plan for Science and Research," the first major deliverable to NASA under the Space Station contract with RSA, was submitted to NASA by the Russian Scientific and Technical Advisory Council (STAC). RSA established STAC to provide peer review of Russian research and technology proposals related to the International Space Station. Fifty Russian organizations submitted more than 250 research proposals, and more than 100 were selected during the first round of peer review, leading to the approval in June 1995 of $3.5 million to support the selected researchers.

In July 1995, the agreement between the United States and Japan concerning the cross-waiver of liability for cooperation in the exploration and use of space for peaceful purposes entered into force. This agreement is to facilitate further space cooperation between the two countries, which is already well established in the areas of human spaceflight, space science, and Mission to Planet Earth. An MOU between NASA and NASDA went into effect in October 1994, providing for the flight of two NASA sensors onboard the Japanese Advanced Earth Observing Satellite (ADEOS).

President Clinton and Ukrainian President Kuchma signed the Agreement Between the United States of America and Ukraine on Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes in November 1994. This Agreement identified NASA and the National Space Agency of Ukraine (NSAU) as the implementing agencies and stated that the United States and Ukraine shall carry out civil space cooperation in such fields as space communications, life and microgravity sciences and applications, and Earth studies. In November 1994, NASA and the Paton Welding Institute in Kiev, Ukraine, initiated a joint project called the International Space Welding Experiment. This project involves the flight demonstration of the Ukrainian Universal Hand Tool (UHT), an electron beam-welding tool developed by Paton, to assess the capability of the UHT to perform new emergency repairs on the International Space Station.

In addition to cooperation with traditional spacefaring partners, cooperation with developing countries, especially in Latin America, was significantly expanding. In the fall of 1994, NASA conducted a series of sounding rocket launches, known as the Guara campaign, from Brazil's Alcantra launch range in coordination with Brazil's National Space Research Institute.

NOAA continued its support for the international satellite-aided search-and-rescue program known as Cospas-Sarsat (from a Russian acronym meaning Space System for the Search of Vessels in Distress and an English one for Search and Rescue Satellite-Aided Tracking). To date, more than 30 countries and organizations are associated formally with Cospas-Sarsat. Since its inception in 1982, Cospas-Sarsat has helped in the rescue of more than 4,600 people. The Cospas-Sarsat space segment (provided by the United States, Russia, France, and Canada) detects distress signals from maritime, aviation, and land-based users and relays them to the appropriate rescue coordination authorities. Cospas-Sarsat is currently supported by six U.S. and Russian polar-orbiting satellites, which provide global coverage, and an international network of ground stations, including six in the United States and its territories. The U.S. Mission Control Center for Cospas-Sarsat is located in NOAA's Suitland, MD, facility.

In September 1995, an intergovernmental Sarsat memorandum of agreement was signed in Washington by the United States, France, and Canada. The new agreement commits its signatory governments to long-term support of satellite-aided search and rescue. It establishes the means by which the Sarsat parties will manage their space segment obligations under the International Cospas-Sarsat Program Agreement, which was signed in 1988 by Russia, the United States, France, and Canada. The 1988 and 1995 agreements are to remain in force through 2003, with automatic 5-year extensions.

NOAA also used search-and-rescue equipment on its GOES-7, GOES-8, and GOES-9 satellites to relay alert data over most of the Western Hemisphere. NOAA and its foreign partners began evaluating the operational use of geostationary satellites and related ground stations to augment Cospas-Sarsat's polar orbiting-system.

DoC's Office of Aerospace pressed for expanded export opportunities for U.S. aircraft manufacturers through negotiations in the World Trade Organization (WTO). The Office of Aerospace has been actively encouraging as many countries as possible to sign the General Agreement on Tariffs and Trade (GATT) Agreement on Trade in Civil Aircraft (Aircraft Agreement) before becoming members of WTO. Negotiations are continuing with key and emerging aerospace manufacturing countries, such as Russia, China, South Korea, and Poland, to sign and implement the provisions of the Aircraft Agreement and the provisions of WTO, especially the Subsidies Code. The Aircraft Agreement eliminates duties on aircraft and most aerospace engines and parts. The Office of Aerospace also participated in U.S. Government efforts to reduce Russian tariffs on imported aircraft and components. This activity caused Russia to lower its tariff from 50 to 30 percent and provide verbal assurances of providing tariff waivers, on a case-by-case basis, for leased U.S. aircraft for the next 7 years.

DoT's Office of Commercial Space Transportation (OCST) provided representation and indepth analytical and policy support to negotiations led by the U.S. Trade Representative (USTR) to establish a commercial space launch trade agreement between the United States and Ukraine. This included participation in two rounds of negotiations held in Kiev and Washington, D.C. DoC's Office of Air and Space Commercialization and its Office of Aerospace also supported these efforts.

The first space launch trade agreement between the United States and the People's Republic of China expired in December 1994. In support of USTR-led trade negotiations for a new agreement, OCST provided expertise in commercial space launch technology and industry concerns. Negotiations were completed in January, and the agreement was signed into force on March 3, 1995. OCST continued to serve as Chair of the Working Groups on Information responsible for monitoring foreign compliance under both the U.S./Russia and U.S./China launch trade agreements. DoC's Office of Air and Space Commercialization and the Office of Aerospace assisted with commercial space launch agreements with Russia and China.

Under the U.S.-Russia Business Development Committee/Aerospace Subgroup, the Office of Aerospace organized a trade visit of Russian aeronautics officials to the United States in November 1994. The event was cosponsored by the U.S. Trade and Development Agency, the FAA, NASA, and the Foreign Trade Association of Southern California. Activities included a press conference highlighting the Russian passenger aircraft IL-96M/T, equipped with U.S. engines and avionics, and a conference titled "Emerging Aerospace Cooperative Opportunities between the U.S. and Russia."

DoC's Office of Aerospace also provided export counseling and trade development support, often in cooperation with other Federal agencies, to support and promote the interests of U.S. air traffic control and airport equipment and service suppliers overseas. In March 1995, the Office of Aerospace co-sponsored with the FAA and the U.S. Trade and Development Agency a symposium on future aviation infrastructure and technology developments in the Asia-Pacific region. The Office of Aerospace continues to provide input and policy guidance on air traffic control technology developments, including the GPS.

During FY 1995, Smithsonian Astrophysical Observatory (SAO) scientists and Russian astronomers worked to set up the U.S. Data Center for the Spectrum-X-Gamma mission, an international collaborative space x-ray observatory led by the Institute for Space Research in Moscow. SAO will collect and archive data from the mission and make the information available worldwide through the Internet. Computers that will give Russian scientists easy access to these data were shipped from SAO to the institute in June 1995. The Spectrum-X-Gamma mission will conduct multiple experiments in a broad wavelength range from ultraviolet through x-rays to gamma rays.

Nearly 200 scientists and engineers from approximately 16 countries attended the Fourth International Conference on Tethers in Space at the Smithsonian Institution in April 1995. Experts from SAO, NASA, the Italian Space Agency, and industry discussed the results of several successful missions using tethered-satellite systems, as well as experiments planned for the future.

International Organizations

DoS served as the lead agency for U.S. delegations at meetings of the International Telecommunications Satellite (INTELSAT) and the International Mobile Satellite (INMARSAT) organizations. It provided relevant policy guidance to Comsat, the U.S. signatory to both of these organizations. DoS participated in the creation of the INTELSAT 2000 Porlamar Working Party in October 1994. It began considering options for restructuring INTELSAT, including the creation of one or more corporate subsidiaries that would function as ordinary multinational companies. DoS worked to support administration objectives that INTELSAT restructuring improves competition in the international satellite market and benefits users. The INTELSAT Twentieth Assembly of Parties endorsed these objectives in August 1995 and created a new working party to implement the subsidiary arrangement. DoS began the task of ensuring that the working party's efforts fulfill the objectives of full and fair competition.

To reflect more clearly the changing nature of its expanded services, INMARSAT changed its name from the International Maritime Satellite Organization to the International *Mobile* Satellite Organization in December 1994. At the 10th session of the INMARSAT Assembly of Parties in December 1994, the assembly decided that

INMARSAT could provide handheld mobile satellite services via an affiliate called ICO, provided that it not interfere with INMARSAT's main purposes—especially its public service obligations—and that there should be no cross-subsidization between ICO and INMARSAT. Additionally, there should be nondiscriminatory access to national markets for all mobile satellite communications networks. Following the Assembly's decision, INMARSAT and some of its signatories set up ICO Global Communications Ltd. to acquire, launch, and operate a constellation of 12 satellites in medium-Earth orbit. In July 1995, ICO placed a $1.3 billion order for these satellites with a U.S. manufacturer. In the interest of fair market competition, DoS sought to ensure that ICO does not benefit indirectly from INMARSAT's treaty status. Similarly, DoS participated in an intersessional working group examining INMARSAT's structure to see whether it could and should be converted from a treaty-based organization into a commercial one without special privileges and immunities.

In FY 1995, the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on Peaceful Uses of Outer Space (COPUOS) continued its discussions on orbital debris and its potential adverse impact on space operations. The debate focused on the development of a continuing, deliberate, specific multiyear plan for the committee's work on space debris. The multiyear work plan adopted by STSC included measurements of space debris, understanding of data and effects of this environment on space systems, modeling of space debris environment and risk assessment, and space debris mitigation measures. The work plan evolved from statements by the United States, France, Germany, Canada, India, and the European Space Agency.

During FY 1995, STSC and the Legal Subcommittee of COPUOS also continued their work on international cooperation in meteorology, space science, space transportation, human space flight, and environmental monitoring. Since its founding in 1958, COPUOS has made significant progress in promoting international collaboration in outer space for science and engineering, communications, transportation, weather forecasting, global change research, and medicine.

Discussions Concerning Arms Control of Space-Related Weaponry

During FY 1995, the U.S. Arms Control and Disarmament Agency (ACDA) participated in the development and implementation of a wide variety of national and international policies relating to missiles and space. ACDA continued to support U.S. efforts to expand and strengthen the 28-member Missile Technology Control Regime (MTCR), which is intended to prevent the proliferation of missiles, space launch vehicles, and other unmanned aerial vehicles capable of delivering weapons of mass destruction. ACDA actively supported U.S. initiatives that resulted in South Africa and Brazil agreeing not to develop or acquire offensive military missiles covered by the MTCR. By meeting these and other membership criteria, both countries were admitted as full members in the MTCR. During this year, ACDA also worked intensively with Russia to resolve various outstanding arms control issues and to help Russia implement comprehensive export controls. The capstone of these efforts was Russia being admitted to the MTCR as well. ACDA also contributed to U.S. regional missile nonproliferation efforts, particularly in southern Asia, aiming to freeze, roll back, and ultimately eliminate ballistic missile programs in India and Pakistan and to prevent the import of such weapons there.

ACDA continued to be involved deeply in the policy process addressing the Strategic Arms Reduction Treaty (START) and the use of U.S. and foreign excess ballistic missiles as space launch vehicles. Regarding the U.S. ballistic missiles that are to become excess under START I and START II, it is U.S. policy to retain them for U.S. Government use or to eliminate them. Since the signing of START I, some of the other START parties have initiated programs for using their excess ballistic missiles for nonmilitary space launch purposes. Such use has both military and proliferation implications. As an active participant in the National Security Council (NSC)-chaired Excess Ballistic Missile Working Group, ACDA assisted in crafting U.S. policy in this area, which is that the U.S. Government will consider, on a case-by-case basis, the requests of U.S. companies to avail themselves of such foreign space launch services. As a member of START's Joint Compliance and Inspection Commission (JCIC), ACDA participated in negotiating an agreement with the JCIC partners, which confirms that any space launch vehicle that employs the first stage of an intercontinental ballistic missile or of a submarine-launched ballistic missile is subject to the START provisions.

ACDA continued its involvement with a number of interagency working groups concerned with missile-related issues during FY 1995. On the international level, ACDA actively supported the United Nations Special Commission on Iraq's (UNSCOM) efforts to destroy or remove from Iraq virtually all materials, equipment, and facilities related to missiles with a range of greater than 150 kilometers.

Space and Public Diplomacy Abroad

In support of its mission to inform foreign publics about official U.S. foreign and domestic initiatives, the U.S. Information Agency (USIA) continued to provide a variety of television programs, electronically delivered texts and articles, and radio broadcasts about U.S. space and aeronautics activities. USIA's more than 200 posts in 147 countries distributed these products to local media and provided public affairs support. As in previous years, Voice of America (VOA) radio broadcasts, Worldnet television's Newsfile reports, and the Wireless File print service provided coverage in multiple languages of Shuttle missions and other NASA programs.

U.S.-Russian cooperation was an important focus for USIA programs in FY 1995. Listeners throughout the world tuned into VOA's live coverage of the *Atlantis* docking with the *Mir* space station in June 1995, while television stations rebroadcast more than 30 Newsfile reports on the mission and its implications. USIA's Information Bureau produced a brochure on U.S.-Russia space cooperation for distribution at the Moscow summit in June 1995, in addition to detailed background articles on the U.S.-Russian space agreement and efforts to build the International Space Station.

USIA programs also demonstrated to foreign audiences the tangible benefits of U.S. space technology, from NASA contributions to biomedical research to data about the Earth's atmosphere gathered by the Perseus project and the use of Shuttle radar to locate an ancient Cambodian city. In September 1995, Worldnet began broadcasting two multipart series on the space program. "Lift-Off to Learning" uses Shuttle missions and astronauts to discuss the basics of space flight, spin-off technologies, and other issues. "Exploring the World Beyond" is a 10-part series on various NASA programs, from Apollo to the Upper Atmosphere Research Satellite.

APPENDICES

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	26[c]	0	1	0
1993	28[c]	1	1	0
1994	31[c]	1	1	0
1995 *(through September 30, 1995)*	17[c,d]	1	0	0
TOTAL	1,335	147	85	15

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[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. It counts separately spacecraft launched by the same launch vehicle.

[d] This counts the five orbital debris radar calibration spheres that were launched from STS-63 as one set of spacecraft.

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[a]	Italy[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	20[c]	62			2	1			9	1	
1992	31[c]	55			2	3			7[b]	2	
1993	24[c]	45			1	1			7[b]		
1994	26[c]	49			2	5			6[b]	2	
1995 *(through Sept. 30)*	18[c]	24			1				9[b]		1
TOTAL	1,042	2,491	10	8	49	37	1	1	73	8	3

[a] Since 1979, all launches for ESA member countries have been joint and are listed under ESA.

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

[c] This includes commercial expendable launches and launches of the Space Shuttle, but because this table records launches rather than spacecraft, it does not include separate spacecraft released from the Shuttle.

APPENDIX **A-3**

Successful U.S. Launches

October 1, 1994–September 30, 1995

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	**Mission Objectives**	**Apogee and Perigee (km), Period (min), Inclination to Equator (°)**	**Remarks**
Oct. 6, 1994 Intelsat 703 64A Atlas IIAS	Provide television, telephone service for N. Pacific region.	35,803 km 35,775 km 23 hrs 56 minutes 0.035°	
Nov. 1, 1994 Wind 71A Delta II	Measure solar wind plasma and magnetic field.	Variable parameters	Part of GGS/ISTP program.
Nov. 3, 1994 Space Shuttle *Atlantis* (STS-66) 73A Space Shuttle	Collect temperature and solar energy data for NASA and NOAA.	310 km 296 km 1 hour 31 minutes 57°	Deployed ATLAS-3, SSBUV, and CRISTA-SPAS-1 payloads.
Nov. 29, 1994 Orion 79A Atlas IIA	Provide television service.	36,022 km 35,621 km 23 hr 58 minutes 30°	German spacecraft.
Dec. 22, 1994 Defense Support Program satellite #17 (USA 107) 84A Titan IV	Early warning missile launch detection.	Geosynchronous—exact parameters not available.	
Dec. 30, 1994 NOAA-14 (NOAA-J before orbit) 89A Atlas E	Measure weather data, such as atmospheric temperature and moisture.	858 km 845 km 1 hour 42 minutes 98.9°	Replaced NOAA-11.
Jan. 10, 1995 Intelsat 704 1A Atlas IIAS	Provide radio and television coverage for MidEast, Africa, and Europe.	35,797 km 35,776 km 23 hrs 56 minutes 0.015°	
Jan. 28, 1995 EHF-F4 (UFO-4) (USA108) 3A Atlas II	Naval communication.	36,388 km 24,474 km 19 hours 31 minutes 5.4°	DoD payload on commercial ELV. First UHF Follow-On to carry EHF package.

APPENDIX **A-3**
(continued)

Successful U.S. Launches

October 1, 1994–September 30, 1995

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Feb. 3, 1995 Space Shuttle *Discovery* (STS-63) 4A Space Shuttle	First close encounter in nearly 20 years between U.S. and Russian spacecraft (*Mir*); prelude to international Space Station.	342 km 310 km 1 hour 31 minutes 51.6°	Carried SPARTAN 204, SSCE, and AMOS payloads.
Feb. 7, 1995 SPARTAN 204 4B STS-63	Far-ultraviolet spectrograph saw galactic dust clouds.	Similar to STS-63	Shuttle Pointed Autonomous Research Tool for Astronomy.
Feb. 7, 1995 ODERACS 2A-2E 4C-4G STS-63	Provide calibration for radar echoes.	Similar to STS-63	Very small Orbital Debris Radar Calibration Spheres.
March 2, 1995 Space Shuttle *Endeavour* (STS-67) 7A Space Shuttle	First ultraviolet images of the Moon taken by ASTRO-2 (trio of ultraviolet telescopes).	363 km 349 km 1 hour 31 minutes 28.5°	Also conducted protein crystal growth experiment.
March 22, 1995 Intelsat 705 13A Atlas IIAS	Telecommunications for Latin America.	35,800 km, 35,776 km, 23 hrs 56 minutes 0.04°	
March 24, 1995 Defense Meteorological Satellite Program DMSP/F13 (USA 109) 15A Atlas E	Replenish DoD meteorological constellation.	854 km 847 km 1 hour 42 minutes 98.8°	Final Atlas E launch.
April 3, 1995 Orbcomm 1&2 17A & 17B Pegasus	Global paging and data communication.	747 km 734 km 1 hour 40 minutes 69.9°	First of 26 planned satellites.
April 3, 1995 Microlab 1 17C Pegasus	Microsatellite with global lightning mapper and GPS radio receiver.	747 km 734 km 1 hour 40 minutes 69.9°	

APPENDIX **A-3**

(continued)

Successful U.S. Launches

October 1, 1994–September 30, 1995

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
April 7, 1995 MSAT (AMSC-1) 19A Atlas IIA	Mobile telephone communication.	Geosynchronous—exact parameters not available.	American Mobile Satellite Corp.
May 14, 1995 DoD classified payload (USA 110) 22A Titan IV	Electronic intelligence.	Parameters not available.	
May 23, 1995 GOES-9 (GOES-J) 25A Atlas I	Image cloud cover; measure atmospheric temperature and moisture.	35,806 km 35,775 km 23 hours 56 minutes 0.07°	Replaced GOES-7 over west coast of United States.
May 31, 1995 EHF-F5 (UFO-5) (USA 111) 27A Atlas II	Naval communication.	Geosynchronous—exact parameters not available	DoD payload on commercial ELV.
June 27, 1995 Space Shuttle *Atlantis* (STS-71) 30A Space Shuttle	Rendezvous with *Mir* space station.	385 km 296 km 1 hour 31 minutes 51.6°	Brought up Mir 19 crew; returned Mir 18 crew to Earth.
July 10, 1995 DoD classified payload (USA 112) 34A Titan IV	Signal intelligence.	39,200 km 1300 km 12 hours 64° (data estimated by Jane's Intelligence Review)	
July 13, 1995 Space Shuttle *Discovery* (STS-70) 35A Space Shuttle	Deploy Tracking and Data Relay Satellite (TDRS).	315 km 287 km 1 hour 31 minutes 28.4°	First Shuttle mission to use new Mission Control Center in Houston.

APPENDIX **A-3**
(continued)

Successful U.S. Launches

October 1, 1994–September 30, 1995

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	**Mission Objectives**	**Apogee and Perigee (km), Period (min), Inclination to Equator (°)**	**Remarks**
July 13, 1995 TDRS-7 35B STS-70	Tracking and Data Relay Satellite (TDRS) for other spacecraft and ground in F and Ku bands.	35,803 km, 35,773 km, 23 hours 56 minutes, 0.43°	
July 31, 1995 Defense Satellite Communications System (DSCS-III) (USA 113) 38A Atlas IIA	Military communication.	Geosynchronous—exact parameters not available.	
Aug. 5, 1995 Koreasat 41A Delta II	Provide South Korean television.	29,798 km 26,777 km 17 hours 42 minutes 0.07°	Failed to reach geostationary orbit initially.
Aug. 28, 1995 JCSat3 43A Atlas IIA	Carry voice, data, and digital television signals.	Geosynchronous—exact parameters not available.	Japan's first regional communications spacecraft.
Sep. 7, 1995 Space Shuttle *Endeavour* (STS-69) 48A Space Shuttle	Deploy SPARTAN and Wake Shield Facility.	~370 km 1 hour 31 minutes 28.4°	
Sep. 8, 1995 SPARTAN 201 48B STS-69	X-ray, far-ultraviolet, and visible light instruments to study solar corona and galactic clusters.	Parameters similar to STS-69	
Sep. 11, 1995 Wake Shield Facility (WSF-2) 48C STS-69	Grow special semiconductors.	Parameters similar to STS-69	Terminated early because of overheating.

APPENDIX **B-1**

U.S.-Launched Applications Satellites, 1988–Sep. 30, 1995

Date	Name	Launch Vehicle	Remarks
		COMMUNICATIONS	
Sep. 29, 1988	TDRS-3	Space Shuttle	Space-based communications and tracking satellite.
Mar. 13, 1989	TDRS-4	Space Shuttle	Space-based communications and tracking satellite.
Sept. 25, 1989	Fltsatcom F-8	Atlas/Centaur	Sixth, and last in series of geosynchronous satellites, for the 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 the 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.
Aug. 2, 1991	TDRS-5	Space Shuttle	Space-based communications and tracking satellite.
Feb. 10, 1992	DSCS III	Atlas II	Launched by the Air Force for 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 DoD.
Aug. 31, 1992	Satcom C4	Delta II	Commercial communications satellite.
Oct. 12, 1992	DFS-3	Delta II	Launched by McDonnell Douglas for German communications.
Jan. 13, 1993	TDRS-6	Space Shuttle	Space-based communications and tracking satellite.
Feb. 9, 1993	OXP-1	Pegasus	Experimental, demonstration satellite for transmitting brief messages with hand-held communicators.
Mar. 25, 1993	UFO-1	Atlas-Centaur I	Launched for the Navy but to a useless orbit.
Jul. 19, 1993	DSCS III	Atlas II	Launched by the Air Force for DoD.
Sep. 3, 1993	UFO-2	Atlas-Centaur I	Second of nine UHF satellites to replace the Navy's Fleet Satellite Communications System.
Sep. 12, 1993	ACTS	Space Shuttle	Test of advanced communications satellite technology.
Nov. 28, 1993	DSCS III	Atlas II	Defense Satellite Communications System satellite.
Dec. 8, 1993	NATO IVB	Delta II	NATO communications satellite for communications with NATO military forces and between NATO nations.
Dec. 16, 1993	Telstar 401	Atlas II	AT&T television and data communications satellite.
Feb. 7, 1994	Milstar	Titan IV	Initial Milstar EHF/UHF secure voice satellite for DoD.
Feb. 19, 1994	Galaxy 1R	Delta II	Hughes video communications satellite.
May 19, 1994	STEP-2	Pegasus	Test satellite to separate adjacent, overlapping cochannel communications.
Jun. 24, 1994	UFO-3	Atlas I	Third of nine UHF satellites to replace the Navy's Fleet Satellite Communications System.
Aug. 3, 1994	DBS-2	Atlas IIA	Commercial television satellite owned by DIRECTV and United States Satellite Broadcasting.
Oct. 6, 1994	Intelsat 703	Atlas IIAS	Provide telecommunications to North Pacific region.
Nov. 29, 1994	Orion	Atlas IIA	German spacecraft.
Jan. 10, 1995	Intelsat 704	Atlas IIAS	Provide telecommunications to MidEast, Africa, and Europe.
Jan. 28, 1995	EHF-F4 (UFO-4)	Atlas II	Navy spacecraft on commercial launch vehicle.
Mar. 22, 1995	Intelsat 705	Atlas IIAS	Provide telecommunications for Latin America.
Apr. 3, 1995	Orbcomm 1 and 2	Pegasus	First of 26 planned satellites for global paging and data communication.
Apr. 7, 1995	MSAT (AMSC-1)	Atlas IIA	American Mobile Satellite Corp.—mobile telephone communications.
May 31, 1995	EHF-F5 (UFO-5)	Atlas II	Navy spacecraft on commercial launch vehicle.
Jul. 13, 1995	TDRS-7	STS-70	Tracking and Data Relay Satellite in F and Ku bands.
Jul. 31, 1995	DSCS-III	Atlas IIA	Defense Satellite Communications System.
Aug. 5, 1995	Koreasat	Delta II	South Korean television.
Aug. 28, 1995	JCSat3	Atlas IIA	Japan's first regional communication satellite.

APPENDIX **B-1**

(continued)

U.S.-Launched Applications Satellites, 1988–Sep. 30, 1995

Date	Name	Launch Vehicle	Remarks
		WEATHER OBSERVATION[a]	
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.
Feb. 9, 1993	SCD 1	Pegasus	Satellite to monitor cloud cover, rainfall, flood and tide levels, and air quality over Brazil.
Aug. 9, 1993	NOAA-13	Atlas E	Launched for NOAA, but communications lost on Aug. 21, 1993.
Apr. 13, 1994	GOES-8	Atlas I	Satellite to provide data on weather and the atmosphere.
Aug. 29, 1994	DMSP F-12	Atlas E	Meteorological satellite for DoD.
Dec. 30, 1994	NOAA-14	Atlas E	Replaced NOAA-11.
Apr. 3, 1995	Microlab 1	Pegasus	Microsatellite with global lightning mapper. Also carries a GPS radio receiver to infer temperature and humidity in path of GPS satellites near the horizon.
Mar. 24, 1995	DMSP/F13	Atlas E	Defense Meteorological Satellite Program. Final Atlas E launch.
May 23, 1995	GOES-9	Atlas I	Replaced GOES-7.
		EARTH OBSERVATION AND GEODESY	
Oct. 23, 1992	LAGEOS II	Space Shuttle	Joint NASA-Italian satellite for a variety of Earth observation and geodetic missions.
Oct. 5, 1993	Landsat-6	Titan II	Launched to monitor Earth resources, but communications lost.
May 9, 1994	MSTI-2	Scout	Satellite to detect ballistic missile launches and also perform environment and ecological monitoring.

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

APPENDIX **B-1**

(continued)

U.S.-Launched Applications Satellites, 1988–Sep. 30, 1995

Date	Name	Launch Vehicle	Remarks
		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 satellites, for DoD.
Aug. 25, 1988	SOOS-4	Scout	Dual satellites, part of Navy navigation system.
Feb. 14, 1989	GPS-1 (Block II)	Delta	Global Positioning System satellite.
June 10, 1989	GPS-2 (Block II)	Delta	Global Positioning System satellite.
Aug. 18, 1989	GPS-3 (Block II)	Delta	Global Positioning System satellite.
Oct. 21, 1989	GPS-4 (Block II)	Delta	Global Positioning System satellite.
Dec. 11, 1989	GPS-5 (Block II)	Delta	Global Positioning System satellite.
Jan. 24, 1990	GPS-6 (Block II)	Delta	Global Positioning System satellite.
Mar. 26, 1990	GPS-7 (Block II)	Delta	Global Positioning System satellite.
Aug. 2, 1990	GPS-8 (Block II)	Delta	Global Positioning System satellite.
Oct. 1, 1990	GPS-9 (Block II)	Delta	Global Positioning System satellite.
Nov. 16, 1990	GPS-10 (Block II)	Delta	Global Positioning System satellite.
Jul. 4, 1991	GPS-11 (Block II)	Delta	Global Positioning System satellite.
Feb. 23, 1992	GPS-12 (Block II)	Delta	Global Positioning System satellite.
Apr. 10, 1992	GPS-13 (Block II)	Delta	Global Positioning System satellite.
Jul. 7, 1992	GPS-14 (Block II)	Delta	Global Positioning System satellite.
Sep. 9, 1992	GPS-15 (Block II)	Delta	Global Positioning System satellite.
Nov. 22, 1992	GPS-16 (Block II)	Delta II	Global Positioning System satellite.
Dec. 18, 1992	GPS-17 (Block II)	Delta II	Global Positioning System satellite.
Feb. 3, 1993	GPS-18 (Block II)	Delta II	Global Positioning System satellite.
Mar. 30, 1993	GPS-19 (Block II)	Delta II	Global Positioning System satellite.
May 13, 1993	GPS-20 (Block II)	Delta II	Global Positioning System satellite.
Jun. 26, 1993	GPS-21 (Block II)	Delta II	Global Positioning System satellite.
Aug. 30, 1993	GPS-22 (Block II)	Delta II	Global Positioning System satellite.
Oct. 26, 1993	GPS (Block II)	Delta II	Global Positioning System satellite.
Mar. 10, 1994	GPS (Block II)	Delta II	Global Positioning System satellite.

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

APPENDIX **B-2**

U.S.-Launched Scientific Satellites, 1988–Sep. 30, 1995

Date	Name	Launch Vehicle	Remarks
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 Ultraviolet 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.
Mar. 30, 1993	SEDS I	Delta II	Comparison of actual tether dynamics with model.
Apr. 11, 1993	SPARTAN-201	Space Shuttle	Study solar wind and Sun's corona.
Jun. 26, 1993	Plasma Motor Generator	Delta II	Demonstrate ability of tether to generate electrical current in space.
Sep. 13, 1993	ORFEUS-SPAS	Space Shuttle	Study very hot and very cold matter in the universe.
Oct. 5, 1993	Landsat-6	Titan II	Satellite to support global change research, but communications lost after succesful launch by Titan II after kick motor failed to place it in final orbit.
Jan. 25, 1994	Clementine	Titan II	Satellite to test missile defense technologies and also provide images of the Moon.
Feb. 9, 1994	BREMSAT	Space Shuttle	Satellite to study such phenomena in space as heat conductivity, the forces of acceleration, and atomic forces.
Mar. 10, 1994	SEDS-II	Delta II	Suspend a tether in space with a minimum of swing.
Sept. 13, 1994	SPARTAN-201	Space Shuttle	Second release of subsatellite to study the solar wind and the Sun's corona.
Nov. 1, 1994	Wind	Delta II	Part of GGS/ISTP program to study solar wind.
Feb. 7, 1995	SPARTAN 204	Space Shuttle	Shuttle Pointed Autonomous Research Tool for Astronomy. Observed galactic dust clouds.
Sep. 8, 1995	SPARTAN 201	Space Shuttle	Studied solar corona and galactic clusters.
Sep. 11, 1995	Wake Shield Facility (WSF-2)	Space Shuttle	Designed to grow special semiconductors. Terminated early because of overheating.

APPENDIX **B-3**

U.S.-Launched Space Probes, 1975–Sep. 30, 1995

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 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 around Saturn in 1981; and went by Uranus in 1986 and Neptune in 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, and 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 one large and three small probes plus spacecraft bus; all descended through Venus atmosphere Dec. 9 and 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; ceased communicating with Earth on Aug. 21, 1993.
Jan. 25, 1994	Clementine	Titan II	Experimental deep space probe that entered lunar orbit on Feb. 19, 1994, and took 1.8 million images of the surface of the Moon during the next 2 1/2 months.

APPENDIX C

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Vostok 1	Apr. 12, 1961	Yury 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	Valery 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 three-person crew.
Voskhod 2	Mar. 18, 1965	Pavel I. Belyayev Aleksey A. Leonov	1:2:2	First extravehicular activity (EVA), by Leonov, 10 min.
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	0:4:53	First U.S. two-person flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, II	4:1:56	21-min. EVA (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 two orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	3:0:21	EVA; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	2:22:47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sep. 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 EVA 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. three-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 two 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.

APPENDIX C

(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

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 11	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 Valery 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 service module. Ship circled Moon, with crew using LM as "lifeboat" until just before reentry.
Soyuz 9	June 1, 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17:16:59	Longest 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 11	June 6, 1971	Georgiy T. Dobrovolskiy Vladislav N. Volkov Viktor I. Patsayev	23:18:22	Docked with Salyut 1, and Soyuz 11 crew occupied space station for 22 days. Crew perished in final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James B. Irwin	12:7:12	Fourth 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 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	Sep. 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.

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(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
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 Yury P. Artyukhin	15:17:30	Docked with Salyut 3 and Soyuz 14 crew occupied space station.
Soyuz 15	Aug. 26, 1974	Gennady V. Sarafanov Lev. S. Demin	2:0:12	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatoly V. Filipchenko Nikolay N. Rukavishnikov	5:22:24	Test of Apollo-Soyuz Test Project (ASTP) configuration.
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 Valery 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	Sep. 15, 1976	Valery F. Bykovskiy Vladimir V. Aksenov	7:21:54	Earth resources study with multispectral camera system.
Soyuz 23	Oct. 14, 1976	Vyacheslav D. Zudov Valery I. Rozhdestvenskiy	2:0:6	Failed to dock with Salyut 5.
Soyuz 24	Feb. 7, 1977	Viktor V. Gorbatko Yury N. Glazkov	17:17:23	Docked with Salyut 5 and occupied station.
Soyuz 25	Oct. 9, 1977	Vladimir V. Kovalenok Valery V. Ryumin	2:0:46	Failed to achieve hard dock with Salyut 6 station.
Soyuz 26	Dec. 10, 1977	Yury 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	Valery 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 Valery 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 Valery V. Ryumin	55:1:29	Docked with Salyut 6. Crew returned in Soyuz 37. Crew duration 184 days, 20 hrs., 12 min.

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U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz 36	May 26, 1980	Valery 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	Yury 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	Sep. 18, 1980	Yury 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 Gennady M. Strekalov	12:19:8	Docked with Salyut 6. First three-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.
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 (OSS 1). Second test of remote manipulator arm. Flight extended 1 day because of flooding at primary landing site; alternate landing site used. Returned for reuse.
Soyuz T-5	May 13, 1982	Anatoly 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 two commercial satellites (SBS 3 and Anik C-3); first flight with four crew members. EVA test canceled when spacesuits malfunctioned.
Space Shuttle *Challenger* (STS-6)	Apr. 4, 1983	Paul J. Weitz Karol J. Bobko Donald H. Peterson Story Musgrave	5:0:24	Sixth flight of Space Shuttle; launched TDRS 1.
Soyuz T-8	Apr. 20, 1983	Vladimir Titov Gennady Strekalov Aleksandr Serebrov	2:0:18	Failed to achieve docking with Salyut 7 station.

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U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
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 two commercial satellites (Anik C-2 and Palapa B-1); also launched and retrieved SPAS 01; first flight with five crew members, 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 1-B); first flight of U.S. black astronaut.
Space Shuttle *Columbia* (STS-9)	Nov. 28, 1983	John W. Young Brewster W. Shaw Owen K. Garriott Robert A. R. Parker Byron K. Lichtenberg Ulf Merbold	10:7:47	Ninth flight of Space Shuttle; first flight of Spacelab 1; first flight of six 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 41-B)	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-11.
Soyuz T-11	Apr. 3, 1984	Yury Malyshev Gennady 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 41-C)	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 Long-Duration Exposure Facility (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 EVA.
Space Shuttle *Discovery* (STS 41-D)	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. nonastronaut.
Space Shuttle *Challenger* (STS 41-G)	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 with seven crew members, including first flight of two U.S. women and one Canadian (Garneau).

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U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Discovery* (STS 51-A)	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 51-C)	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 51-D)	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 51-B)	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 51-G)	June 17, 1985	Daniel C. Brandenstein John O. Creighton Shannon W. Lucid John M. Fabian Steven R. Nagel Patrick Baudry Prince Sultan Salman 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 crew members.
Space Shuttle *Challenger* (STS 51-F)	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 51-I)	Aug. 27, 1985	Joe H. Engle Richard O. Covey James D. van Hoften William F. Fisher John M. Lounge	7:2:18	Twentieth STS flight. Launched three communications satellites. Repaired Syncom IV-3.
Soyuz T-14	Sep. 17, 1985	Vladimir Vasyutin Georgiy 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 51-J)	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.

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U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Challenger* (STS 61-A)	Oct. 30, 1985	Henry W. Hartsfield Steven R. Nagel Bonnie J. Dunbar James F. Buchli Guion S. Bluford, Jr. 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 61-B)	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 61-C)	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	Yury 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 Yury Romanenko. Viktorenko and Faris returned in Soyuz TM-2, July 30, with Aleksandr Laveykin who experienced medical problems. Faris first Syrian in space.
Soyuz TM-4	Dec. 21, 1987	Vladimir Titov Musa Manarov Anatoly Levchenko	180:5	Docked with *Mir* space station. Crew of Yury Romanenko, Aleksandr Aleksandrov, and Anatoly 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.
Soyuz TM-6	Aug. 29, 1988	Vladimir Lyakhov Valery Polyakov Abdul Mohmand	8:19:27	Docked with *Mir* space station; Mohmand first Afghanistani in space. Crew returned Sept. 7, in Soyuz TM-5.
Space Shuttle *Discovery* (STS-26)	Sep. 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 Valery Polyakov returned Apr. 27, 1989, in Soyuz TM-7.

APPENDIX C

(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Atlantis* (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.
Space Shuttle *Discovery* (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.
Space Shuttle *Atlantis* (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.
Space Shuttle *Columbia* (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	Sep. 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.
Space Shuttle *Atlantis* (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.
Space Shuttle *Discovery* (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.
Space Shuttle *Columbia* (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 LDEF.
Soyuz TM-9	Feb. 11, 1990	Anatoly Solovyov Aleksandr Balandin	178:22:19	Docked with *Mir* space station. Crew returned Aug. 9, 1990, in Soyuz TM-9.
Space Shuttle *Atlantis* (STS-36)	Feb. 28, 1990	John O. Creighton John H. Casper David C. Hilmers Richard H. Mullane Pierre J. Thuot	4:10:19	Thirty-fourth STS flight. Dedicated DoD mission.
Space Shuttle *Discovery* (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	Gennady Manakov Gennady Strekalov	130:20:36	Docked with *Mir* space station. Crew returned Dec. 10, 1990, with Toyohiro Akiyama, Japanese astronaut.

APPENDIX C

(continued)

U.S. and Russian Human Spaceflights, 1961-Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Discovery* (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.
Space Shuttle *Atlantis* (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.
Space Shuttle *Columbia* (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 Gennady Manakov and Gennady Strekalov.
Space Shuttle *Atlantis* (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.
Space Shuttle *Discovery* (STS-39)	Apr. 28, 1991	Michael L. Coats Blaine Hammond, Jr. Gregory L. Harbaugh Donald R. McMonagle Guion S. Bluford, Jr. 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	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.
Space Shuttle *Columbia* (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.
Space Shuttle *Atlantis* (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).
Space Shuttle *Discovery* (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).

APPENDIX C

(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

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.
Space Shuttle *Atlantis* (STS-44)	Nov. 24, 1991	Frederick D. Gregory Tom Henricks Story Musgrave Mario Runco, Jr. Tom Hennen	6:22:51 Jim Voss	Forty-fourth STS flight. Launched Defense Support Program (DSP) satellite.
Space Shuttle *Discovery* (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.
Space Shuttle *Atlantis* (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).
Space Shuttle *Endeavour* (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.
Space Shuttle *Columbia* (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)	189:17:43[a]	Docked with *Mir* space station Jul. 29. Tognini returned to Earth in TM-14 capsule with Alexandr Viktorenko and Alexandr Kaleri. Solovyov and Avdeyev spent over six months in the *Mir* orbital complex and returned to Earth in the descent vehicle of the TM-15 spacecraft on Feb. 1, 1993.

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[a] Figures supplied by Marcia S. Smith, Congressional Research Service, Library of Congress, based on information in *Tass*.

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U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Atlantis* (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-ninth STS flight. Deployed Tethered Satellite System-1 and Eureka-1.
Space Shuttle *Endeavour* (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	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.
Space Shuttle *Columbia* (STS-52)	Oct. 22, 1992	James D. Wetherbee Michael A. Baker William M. Shepherd Tamara E. Jernigan Charles L. Veach Steven G. MacLean	9:20:57	Fifty-first STS flight. Studied influence of gravity on basic fluid and solidification processes using U.S. Microgravity Payload-1 in an international mission. Deployed second Laser Geodynamics Satellite and Canadian Target Assembly.
Space Shuttle *Discovery* (STS-53)	Dec. 2, 1992	David M. Walker Robert D. Cabana Guion S. Bluford, Jr. James S. Voss Michael Richard Clifford	7:7:19	Fifty-second STS flight. Deployed the last major DoD classified payload planned for Shuttle (DoD 1) with ten different secondary payloads.
Space Shuttle *Endeavour* (STS-54)	Jan. 13, 1993	John H. Casper Donald R. McMonagle Gregory J. Harbaugh Mario Runco, Jr. Susan J. Helms	6:23:39	Fifty-third STS flight. Deployed Tracking and Data Relay Satellite-6. Operated Diffused X-ray Spectrometer Hitchhiker experiment to collect data on stars and galactic gases.
Soyuz TM-16	Jan. 24, 1993	Gennady Manakov Aleksandr Poleshchuk	179:0:44[a]	Docked with Mir Space Station Jan. 26. On July 22, 1993, the TM-16 descent cabin landed back on Earth with Manakov, Poleschuk, and French cosmonaut Jean-Pierre Haignere from Soyuz TM-17 on board.
Space Shuttle *Discovery* (STS-56)	Apr. 8, 1993	Kenneth D. Cameron Stephen S. Oswald C. Michael Foale Kenneth D. Cockerell Ellen Ochoa	9:6:9	Fifty-fourth STS flight. Completed second flight of Atmospheric Laboratory for Applications and Science and deployed SPARTAN-201.
Space Shuttle *Columbia* (STS-55)	Apr. 26, 1993	Steven R. Nagel Terence T. Henricks Jerry L. Ross Charles J. Precourt Bernard A. Harris, Jr. Ulrich Walter (Germany) Hans W. Schlegel (Germany)	9:23:39	Fifty-fifth STS flight. Completed second German microgravity research program in Spacelab D-2.

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(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Endeavour* (STS-57)	Jun. 21, 1993	Ronald J. Grabe Brian J. Duffy G. David Low Nancy J. Sherlock Peter J. K. Wisoff Janice E. Voss	9:23:46	Fifty-sixth STS flight. Carried Spacelab commercial payload module and retrieved European Retrievable Carrier in orbit since August 1992.
Soyuz TM-17	Jul. 1, 1993	Vasiliy Tsibliyev Aleksandr Serebrov Jean-Pierre Haignere	196:17:45[a]	Docked with Mir space station July 3. Haignere returned to Earth with Soyuz TM-16. Serebrov Tsibliyev landed in TM-17 spacecraft after end of fiscal year on Jan. 14, 1994.
Space Shuttle *Discovery* (STS-51)	Sep. 12, 1993	Frank L. Culbertson, Jr. William F. Readdy James H. Newman Daniel W. Bursch Carl E. Walz	9:20:11	Fifty-seventh STS flight. Deployed ACTS satellite to serve as testbed for new communications satellite technology and U.S./German ORFEUS-SPAS.
Space Shuttle *Columbia* (STS-58)	Oct. 18, 1993	John E. Blaha Richard A. Searfoss M. Rhea Seddon Shannon W. Lucid David A. Wolf William S. McArthur Martin J. Fettman	14:0:29	Fifty-eighth STS flight. Carried Spacelab Life Sciences-2 payload to determine the effects of microgravity on human and animal subjects.
Space Shuttle *Endeavour* (STS-61)	Dec. 2, 1993	Richard O. Covey Kenneth D. Bowersox Tom Akers Jeffrey A. Hoffman Kathryn C. Thornton Claude Nicollier F. Story Musgrave	10:19:58	Fifty-ninth STS flight. Restored planned scientific capabilitities and reliability of the Hubble Space Telescope.
Soyuz TM-18	Jan. 8, 1994	Viktor Afanasyev Yuri Usachev Valery Polyakov	182:0:27[a]	Docked with *Mir* space station Jan. 10. Afanasyev and Usachev landed in the TM-18 spacecraft on July 9, 1994. Polyakov remained aboard *Mir* in the attempt to establish a new record for endurance in space.
Space Shuttle *Discovery* (STS-60)	Feb. 3, 1994	Charles F. Bolden, Jr. Kenneth S. Reightler, Jr. N. Jan Davis Ronald M. Sega Franklin R. Chang-Diaz Sergei K. Krikalev (Russia)	8:7:9	Sixtieth STS flight. Carried the Wake Shield Facility to generate new semi-conductor films for advanced electronics. Also carried SPACEHAB. Krikalev's presence signified a new era incooperation in space between Russia and the United States.
Space Shuttle *Columbia* (STS-62)	Mar. 9, 1994	John H. Casper Andrew M. Allen Pierre J. Thuot Charles D. Gemar Marsha S. Ivins	13:23:17	Sixty-first STS flight. Carried U.S. Microgravity Payload-2 to conduct experiments in materials processing, biotechnology, and other areas.

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APPENDIX C

(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Endeavour* (STS-59)	Apr. 9, 1994	Sidney M. Gutierrez Kevin P. Chilton Jerome Apt Michael R. Clifford Linda M. Godwin Thomas D. Jones	11:5:50	Sixty-second STS flight. Carried the Space Radar Laboratory-1 to gather data on the Earth and the effects humans have on its carbon, water, and energy cycles.
Soyuz TM-19	July 1, 1994	Yuri I. Malenchenko Talgat A. Musabayev	125:22:53[a]	Docked with Mir space station July 3. Both Malenchenko and Musabayev returned to Earth with the Soyuz TM-19 spacecraft, landing in Kazakhstan on Nov. 4 together with Ulf Merbold of Germany, who went up aboard Soyuz TM-20 on Oct 3, 1994. Merbold gathered biological samples on the effects of weightlessness on the human body in the first of two ESA missions to *Mir* to prepare for the International Space Station.
Space Shuttle *Columbia* (STS-65)	July 8, 1994	Robert D. Cabana James D. Halsell, Jr. Richard J. Hieb Carl E. Walz Leroy Chiao Donald A. Thomas Chiaki Naito-Mukai (Japan)	14:17:55	Sixty-third STS flight. Carried International Microgravity Laboratory-2 to conduct research into the behavior of materials and life in near weightlessness.
Space Shuttle *Discovery* (STS-64)	Sep. 9, 1994	Richard N. Richards L. Blaine Hammond, Jr. J. M. Linenger Susan J. Helms Carl J. Meade Mark C. Lee	10:22:50	Sixty-fourth STS flight. Used LIDAR In-Space Technology Experiment to perform atmospheric research. Included the first untethered spacewalk by astronauts in over 10 years.
Space Shuttle *Endeavour* (STS-68)	Sep. 30, 1994	Michael A. Baker Terrence W. Wilcutt Thomas D. Jones Steven L. Smith Daniel W. Bursch Peter J. K. Wisoff	11:5:36	Sixty-fifth STS flight. Used Space Radar Laboratory-2 to provide scientists with data to help distinguish human-induced environmental change from other natural forms of change.
Soyuz TM-20	Oct. 3, 1994	Alexsandr Viktorenko Telena Kondakova Ulf Merbold (ESA)	*	Soyuz TM-19 returned to Earth on Nov. 4, 1994, with Yuri Malenchenko, Talgat Musabayev, and Ulf Merbold. Valeriy Polyakov remained aboard *Mir*.
Space Shuttle *Atlantis* (STS-66)	Nov. 3, 1994	Donald R. McMonagle Curtis L. Brown, Jr. Ellen Ochoa Joseph R. Tanner Jean-Francois Clervoy (ESA) Scott E. Parazynski	10:22:34	Sixty-sixth STS flight. Three main payloads: the third Atmospheric Laboratory for Applications and Science (ATLAS-3), the first Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite (CRISTA-SPAS-1), and the Shuttle Solar Backscatter Ultraviolet (SSBUV) spectrometer . Astronauts also conducted protein crystal growth experiments.

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[a] Figures supplied by Marcia S. Smith, Congressional Research Service, Library of Congress, based on information in *Tass*.

* *Mir* crew members stayed for various and overlapping lengths of time.

APPENDIX C

(continued)

U.S. and Russian Human Spaceflights, 1961–Sep. 30, 1995

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Discovery* (STS-59)	Feb. 3, 1995	James D. Wetherbee Eileen M. Collins Bernard A. Harris, Jr. C. Michael Foale Janice E. Voss Vladimir G. Titov (Russia)	8:6:28	Sixty-seventh STS flight. Primary objective: first close encounter in nearly 20 years between American and Russian spacecraft as a prelude to establishment of International Space Station. (Shuttle flew close by to *Mir*.) Main Payloads: Spacehab 3 experiments and Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN) 204, Solid Surface Combustion Experiment (SSCE), and Air Force Maui Optical Site (AMOS) Calibration Test. Also launched very small Orbital Debris Radar Calibration Spheres (ODERACS).
Space Shuttle *Endeavour* (STS-67)	Mar. 2, 1995	Stephen S. Oswald William G. Gregory John M. Grunsfeld Wendy B. Lawrence Tamara E. Jernigan Ronald A. Parise Samuel T. Durrance	16:15:8	Sixty-eighth STS flight. Longest Shuttle mission to date. Primary payload was a trio of ultraviolet telescopes called Astro-2.
Soyuz TM-21	Mar. 14, 1995	Vladimir Dezhurov Gennadi Strekalov Norman Thagard (U.S.)	*	Thagard was the first American astronaut to fly on a Russian rocket and to stay on the *Mir* space station. Soyuz TM-20 returned to Earth on Mar. 22, 1995, with Valeriy Polyakov, Alexsandr Viktorenko, and Yelena Kondakova. Polyakov set world record by remaining in space for 438 days.
Space Shuttle *Atlantis* (STS-71)	June 27, 1995	Robert L. Gibson Charles J. Precourt Ellen S. Baker Gregory Harbaugh Bonnie J. Dunbar	9:19:22	Sixty-ninth STS flight and one hundredth U.S. human spaceflight. Docked with *Mir* space station. Brought up Mir 19 crew (Anatoly Y. Solovyev and Nikolai M. Budarin). Returned to Earth with Mir 18 crew (Vladimir N. Dezhurov, Gennady M. Strekalov, and Norman Thagard). Thagard set an American record by remaining in space for 115 days.
Space Shuttle *Discovery* (STS-70)	July 13, 1995	Terence Henricks Kevin R. Kregel Nancy J. Currie Donald A. Thomas Mary Ellen Weber	8:22:20	Seventieth STS flight. Deployed Tracking and Data Relay Satellite (TDRS). Also conducted various biomedical experiments.
Soyuz TM-22	Sep. 3, 1995	Yuri Gidzenko Sergei Avdeev Thomas Reiter (ESA)	*	Soyuz TM-21 returned to Earth on Sep. 11, 1995, with Mir 19 crew (Anatoliy Solovyev and Nikolay Budarin).
Space Shuttle *Endeavour* (STS-69)	Sep. 7, 1995	David M. Walker Kenneth D. Cockrell James S. Voss James H. Newman Michael L. Gernhardt	10:20:28	Seventy-first STS flight. Deployed Wake Shield Facility (WSF-2) and SPARTAN 201-03.

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* Mir crew members stayed for various and overlapping lengths of time.

APPENDIX D

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[bc]	Max. Dia x Height (m)	Max. Payload (kg)[d]			First Launch[f]
					185-Km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[e]	
Pegasus				6.71x15.5[h]	380 280[e]	—	210	1990
	1. Orion 50S	Solid	484.9	1.28x8.88				
	2. Orion 50	Solid	118.2	1.28x2.66				
	3. Orion 38	Solid	31.9	0.97x1.34				
Pegasus XL				6.71x16.93	460 350[e]	—	335	1994[g]
	1. Orion 50S-XL	Solid	743.3	1.28x10.29				
	2. Orion 50-XL	Solid	201.5	1.28x3.58				
	3. Orion 38	Solid	31.9	0.97x1.34				
Taurus				2.34x28.3	1400 1080[e]	255	1020	Not scheduled
	0. Castor 120	Solid	1687.7	2.34x11.86				
	1. Orion 50S	Solid	580.5	1.28x8.88				
	2. Orion 50	Solid	138.6	1.28x2.66				
	3. Orion 38	Solid	31.9	0.97x1.34				
Delta II (7920, 7925)				2.44x29.70	5089 3890[e]	1842[i]	3175	1990, Delta-7925 [1960, Delta]
	1. RS-270/A	LOX/RP-1	1043.0 (SL)	3.05x38.1				
	Hercules GEM (9).	Solid	487.6 (SL)	1.01x12.95				
	2. AJ10-118K	N_20_4/A-50	42.4	2.44x5.97				
	3. Star 48B[j]	Solid	66.4	1.25x2.04				
Atlas E				3.05x28.1	820[e] 1860[ek]	—	910[k]	1968, Atlas F [1958, Atlas LV-3A]
	1. Atlas: MA-3	LOX/RP-1	1739.5 (SL)	3.05x21.3				
Atlas I				4.2x43.9	—	2255	—	1990, I [1966, Atlas Centaur]
	1. Atlas: MA-5	LOX/RP-1	1952.0 (SL)	3.05x22.16				
	2. Centaur I: RL10A-3-3A (2)	LOX/LH_2	73.4/engine	3.05x9.14				
Atlas II				4.2x47.5	6580 5510[e]	2810	4300	1991, II [1966, 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/engine	3.05x10.05				
Atlas IIA				4.2x47.5	6828 6170[e]	3062	4750	1992, Atlas IIA [1966, Atlas Centaur]
	1. Atlas: MA-5A	LOX/RP-1	2110.0 (SL)	3.05x24.9				
	2. Centaur II: RL10A-4 (2)	LOX/LH_2	92.53/engine	3.05x10.05				
Atlas IIAS				4.2x47.5	8640 7300[e]	3606	5800	1993, IIAS [1966, Atlas Centaur]
	1. Atlas: MA-5A	LOX/RP-1	2110.0 (SL)	3.05x24.9				
	Castor IVA (4)[j]	Solid	433.6 (SL)	1.01X11.16				
	2. Centaur II: RL10A-4 (2)	LOX/LH_2	92.53/engine	3.05x10.05				

APPENDIX D

(continued)

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[bc]	Max. Dia x Height (m)	Max. Payload (kg)[d]			First Launch[f]
					185-Km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[e]	
Titan II				3.05x42.9	1905[e]	—	—	1988, Titan II SLV [1964, Titan II Gemini]
	1. LR-87-AJ-5 (2)	N_20_4/A-50	1045.0	3.05x21.5				
	2. LR-91-AJ-5	N_20_4/A-50	440.0	3.05x12.2				
Titan III				3.05x47.3	14515	5000[l]	—	1989, Titan III [1964, Titan IIIA]
	0. Titan III SRM (2) (5-1/2 segments)	Solid	6210.0	3.11x27.6				
	1. LR87-AJ-11 (2)	N_20_4/A-50	1214.5	3.05x24.0				
	2. LR91-AJ-11	N_20_4/A-50	462.8	3.05x10.0				
Titan IV				3.05x62.2	17700 14110[e]	6350[m]	—	1989 Titan IV
	0. Titan IV SRM (2) (7 segments)	Solid	7000.0	3.11x34.1				
	1. LR87-AJ-11 (2)	N_20_4/A-50	1214.5	3.05x26.4				
	2. LR91-AJ-11	N_20_4/A-50	462.8	3.05x10.0				
Titan IV/ Centaur				4.3x62.2	—	5760[a]	—	1994, Titan IV Centaur
	0. Titan IV SRM (2) (7 segments)	Solid	7000.0	3.11x34.1				
	1. LR87-AJ-11 (2)	N_20_4/A-50	1214.5/engine	3.05x26.4				
	2. LR91-AJ-11(1)	N_20_4/A-50	462.5	3.05x10.0				
	3. Centaur: RL-10A-3-3A	LOX/LH_2	73.4	4.3x9.0				
	4. SRMU (3 segments)		7690	3.3x34.3				
Space Shuttle[n]				23.79x56.14[h]	24900[o]	5900[p]	—	1981, *Columbia*
	1. SRB: Shuttle SRB (2)	Solid	11790.0(SL)	3.70x45.46				
	2. Orbiter/ET:SSME (3)	LOX/LH_2	1668.7(SL)	8.41x47.00 (ET) 23.79x37.24[h] (orbiter)				
	3. Orbiter/OMS: OMS engines (2)	N_20_4/MMH	26.7	23.79x37.24[h]				

APPENDIX **D**
(continued)

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[bc]	Max. Dia x Height (m)	Max. Payload (kg)[d]			First Launch[f]
					185-Km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[e]	

NOTES:

[a] Propellant abbreviations used are as follows:
A-50 = Aerozine 50 (50% Monomethyl Hydrazine,
50% Unsymmetrical Dimethyl Hydrazine)
RP-1 = Rocket Propellant 1 (kerosene)
Solid = Solid Propellant (any type)
LH_2 = Liquid Hydrogen
LOX = Liquid Oxygen
MMH = Monomethyl Hydrazine
N_20_4 = Nitrogen Tetroxide

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

[c] Thrust per engine. Multiply by number of engines for thrust per stage.

[d] Inclination of 28.5° except where indicated.

[e] Polar launch from Vandenberg AFB, CA.

[f] First successful orbital launch [ditto of initial version].

[g] First launch was a failure

[h] Diameter dimension represents vehicle wing span.

[i] Applies to Delta II-7925 version only.

[j] Two Castor IVA motors ignited at lift-off. Two Castor IVA motors ignited at approximately 57 seconds into flight.

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

[l] With Transfer Orbit Stage (TOS).

[m] With appropriate upper stage.

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

[o] 204 km circular orbit.

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

[q] Titan IV/Centaur is designed for 3 burns directly to geosynchronous orbit.

[r] The first Taurus launch used a Peacekeeper first stage as stage 0 in 1994.

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

APPENDIX E-1A

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY—BUDGET AUTHORITY
(in millions of real-year 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	34	...	...	...	...	...	...	785
1960	524	462	561	43	43	...	...	...	0.1	...	...	1,066
1961	964	926	814	69	68	...	...	...	1	...	...	1,809
1962	1,825	1,797	1,298	200	148	51	...	...	1	...	...	3,295
1963	3,673	3,626	1,550	259	214	43	...	...	2	...	...	5,435
1964	5,100	5,016	1,599	216	210	3	...	...	3	...	...	6,831
1965	5,250	5,138	1,574	244	229	12	...	...	3	...	...	6,956
1966	5,175	5,065	1,689	217	187	27	...	...	3	...	...	6,971
1967	4,966	4,830	1,664	216	184	29	...	...	3	...	...	6,710
1968	4,587	4,430	1,922	177	145	28	0.2	1	3	...	...	6,529
1969	3,991	3,822	2,013	141	118	20	0.2	1	2	...	...	5,976
1970	3,746	3,547	1,678	115	103	8	1	1	2	...	...	5,340
1971	3,311	3,101	1,512	127	95	27	2	1	2	...	...	4,740
1972	3,307	3,071	1,407	97	55	31	6	2	3	...	...	4,575
1973	3,406	3,093	1,623	109	54	40	10	2	3	...	...	4,825
1974	3,037	2,759	1,766	116	42	60	9	3	2	...	...	4,641
1975	3,229	2,915	1,892	106	30	64	8	2	2	...	...	4,913
1976	3,550	3,225	1,983	111	23	72	10	4	2	...	...	5,319
Transition Quarter	932	849	460	32	5	22	3	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	177	59	98	10	8	2	...	...	7,243
1980	5,240	4,680	3,848	161	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	5,528	6,679	235	61	145	12	15	2	...	...	12,442
1983	6,875	6,328	9,019	242	39	178	5	20	...[a]	...	...	15,589
1984	7,458	6,858	10,195	292	34	236	3	19	...	...	...	17,345
1985	7,573	6,925	12,768	474	34	423	2	15	...	...	...	20,167
1986	7,807	7,165	14,126	369	35	309	2	23	...	...	...	21,660
1987	10,923	9,809[b]	16,287	354	48	278	8	19	...	1	...	26,450
1988	9,062	8,322	17,679	626	241	352	14	18	...	1	...	26,627
1989	10,969	10,097	17,906	444	97	301	17	21	...	3	5	28,447
1990	12,324	11,460	15,616	387	79	243	31	25	...	4	5	27,463
1991	14,016	13,046	14,181	566	251	251	29	26	...	4	5	27,793
1992	14,317	13,199	15,023	624	223	327	34	29	...	4	7	28,846
1993	14,310	13,064	14,106	559	165	324	33	25	...	4	8	27,729
1994	14,570	13,022	13,166	461	74	312	31	31	...	5	8	26,649
1995	13,854	12,543	10,644	489	60	352	31	32	...	6	8	23,676

[a] NSF funding of balloon research transferred to NASA.

[b] Includes $2.1 billion for replacement of shuttle orbiter *Challenger*.

[c] "Other" column is the total of the non-NASA, non-DoD budget authority figures that appear in succeeding columns. The total is sometimes different from the sum of the individual figures because of rounding. The "Total Space" column does not include the "NASA Total" column because it includes budget authority for aeronautics as well as space.

[d] EPA has recalculated its aeronautics and space expenditures since 1989, making them significantly higher than reported in previous years.

SOURCE: Office of Management and Budget.

APPENDIX **E-1B**

Space Activities of the U.S. Government

BUDGET AUTHORITY IN MILLIONS OF EQUIVALENT FY 1993 DOLLARS
(adjusted for inflation)

Fiscal Year	GDP Inflator to 1995 $	NASA Total	NASA Space	Defense	Other	Energy	Commerce	Interior	Agriculture	NSF	DoT	EPA	Total Space
1959	5.0958	1,687	1,330	2,497	173	173	0	0	0	0	0	0	4,000
1960	4.9766	2,608	2,299	2,792	214	214	0	0	0	0.5	0	0	5,306
1961	4.9313	4,754	4,566	4,014	340	335	0	0	0	5	0	0	8,921
1962	4.8448	8,842	8,706	6,289	969	717	247	0	0	5	0	0	15,964
1963	4.7613	17,488	17,264	7,380	1,233	1,019	205	0	0	10	0	0	25,878
1964	4.6924	23,931	23,537	7,503	1,014	985	14	0	0	14	0	0	32,054
1965	4.5912	24,104	23,590	7,227	1,120	1,051	55	0	0	14	0	0	31,937
1966	4.4573	23,066	22,576	7,528	967	834	120	0	0	13	0	0	31,072
1967	4.3093	21,400	20,814	7,171	931	793	125	0	0	13	0	0	28,916
1968	4.1536	19,052	18,400	7,983	736	602	116	0.8	4	12	0	0	27,119
1969	3.9549	15,784	15,116	7,961	558	467	79	0.8	4	8	0	0	23,635
1970	3.7515	14,053	13,307	6,295	431	386	30	4	4	8	0	0	20,033
1971	3.5661	11,807	11,058	5,392	453	339	96	7	4	7	0	0	16,903
1972	3.3892	11,208	10,408	4,769	329	186	105	20	7	10	0	0	15,506
1973	3.2290	10,998	9,987	5,241	352	174	129	32	6	10	0	0	15,580
1974	3.0000	9,111	8,277	5,298	348	126	180	27	9	6	0	0	13,923
1975	2.7289	8,812	7,955	5,163	289	82	175	22	5	5	0	0	13,407
1976	2.5340	8,996	8,172	5,025	281	58	182	25	10	5	0	0	13,478
TQ*	2.4461	2,280	2,077	1,125	78	12	54	7	2	2	0	0	3,280
1977	2.3445	8,951	8,065	5,655	307	52	213	23	14	5	0	0	14,027
1978	2.1796	8,849	7,897	5,968	342	74	225	22	17	4	0	0	14,207
1979	2.0056	9,218	8,082	6,089	355	118	197	20	16	4	0	0	14,526
1980	1.8396	9,640	8,609	7,079	296	74	171	22	26	4	0	0	15,984
1981	1.6698	9,214	8,335	8,062	264	68	145	20	27	3	0	0	16,661
1982	1.5540	9,393	8,591	10,379	365	95	225	19	23	3	0	0	19,335
1983	1.4921	10,258	9,442	13,457	361	58	266	7	30	0	0	0	23,260
1984	1.4292	10,659	9,801	14,570	417	49	337	4	27	0	0	0	24,789
1985	1.3766	10,425	9,533	17,576	653	47	582	3	21	0	0	0	27,762
1986	1.3369	10,437	9,579	18,885	493	47	413	3	31	0	0	0	28,957
1987	1.2984	14,182	12,736	21,147	460	62	361	10	25	0	1	0	34,343
1988	1.2529	11,354	10,427	22,150	784	302	441	18	23	0	1	0	33,361
1989	1.1989	13,151	12,105	21,467	532	116	361	20	25	0	4	6	34,105
1990	1.1495	14,167	13,174	17,951	445	91	279	36	29	0	5	6	31,570
1991	1.1037	15,470	14,399	15,652	625	277	277	32	29	0	4	6	30,675
1992	1.0720	15,348	14,149	16,105	669	239	351	36	31	0	4	8	30,923
1993	1.0471	14,984	13,679	14,770	585	173	339	35	26	0	4	8	29,035
1994	1.0270	14,963	13,373	13,521	473	76	320	32	32	0	5	8	27,368
1995	1	13,854	12,543	10,644	489	60	352	31	32	0	6	8	23,676

* Transition Quarter

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**		
	1993 actual	**1994 actual**	**1995 estimated**	**1993 actual**	**1994 actual**	**1995 estimated**
NASA	13,064	13,022	12,543	13,092	12,363	12,593
Defense	14,106	13,166	10,644	13,779	10,973	11,494
Energy	165	74	60	165	83	70
Commerce	324	312	352	295	297	330
Interior	33	31	31	31	31	31
Agriculture	25	31	32	25	30	32
Transportation	4	5	6	4	5	6
EPA	8	8	8	7	8	8
TOTAL	27,729	26,649	23,676	27,398	23,790	24,564

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**		
	1993 actual	**1994 actual**	**1995 estimated**	**1993 actual**	**1994 actual**	**1995 estimated**
NASA[a]	1,245	1,546	1,310	1,212	1,330	1,153
Defense[b]	7,582	6,848	7,119	7,572	7,203	7,072
Transportation[c]	2,532	2,309	2,212	2,378	2,604	2,915
TOTAL	11,359	10,703	10,641	11,162	11,137	11,140

[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.

SOURCE: Office of Management and Budget.

APPENDIX **F-1**

MEMORANDUM OF AGREEMENT
Between the
DEPARTMENT OF COMMERCE
DEPARTMENT OF DEFENSE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
for the
NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

I. PREFACE

On 5 May 1994, the President directed convergence of the Department of Commerce (DOC) National Oceanic and Atmospheric Administration's (NOAA) Polar-orbiting Operational Environmental Satellite (POES) program and the Department of Defense (DoD) Defense Meteorological Satellite Program (DMSP). These two programs will become the National Polar-orbiting Operational Environmental Satellite System which will satisfy civil and national security operational requirements. In addition, the National Aeronautics and Space Administration (NASA), through its Earth Observing System (EOS) efforts, offers new remote sensing and spacecraft technologies that could potentially improve the capabilities of the operational system. The President also directed DoD, DOC, and NASA to establish an Integrated Program Office (IPO) to manage this converged system.

II. PURPOSE

This document constitutes the formal agreement, including roles and responsibilities, between DOC, DoD and NASA, hereafter referred to as "the agencies," to implement the President's directive to establish the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

III. AUTHORITY

This agreement implements Presidential Decision Directive NSTC-2, 5 May 1994, and implements the White House Office of Science and Technology Policy's "Implementation Plan for a Converged Polar-orbiting Environmental Satellite System," dated 2 May 1994. This document provides the necessary authority and responsibility to manage all aspects of the NPOESS. NOAA enters this agreement pursuant to its authority at 15 USC 1525; 49 USC 1463 and 15 USC 313.

IV. NPOESS PROGRAM ORGANIZATION AND RESPONSIBILITIES

The NPOESS program will satisfy the U.S. Government's fundamental civil and national security requirements for collection and distribution of operational polar satellite-based, remotely-sensed meteorological, oceanographic, climatic, and space environmental data. The NPOESS will be composed of four components: spacecraft and sensors; launch support; command, control, and communications; and user interface. Management and implementation of the NPOESS program will be accomplished by the Integrated

Program Office (IPO) under a triagency Executive Committee (EXCOM). The responsibilities and functions of these organizations are as follows:

A. Executive Committee

The Under Secretary of Commerce for Oceans and Atmosphere, the Under Secretary of Defense for Acquisition and Technology, and the NASA Deputy Administrator will form the NPOESS EXCOM. Each EXCOM member will be accountable to the EXCOM for his/her agency's support of the NPOESS. The EXCOM will provide policy guidance; ensure sustained agency support (to include funding); approve the annual budget; approve the NPOESS staffing plan; approve the acquisition program baseline (cost, schedule, performance) and major changes to the baselines as proposed by the System Program Director (SPD); endorse the NPOESS requirements baseline; and approve or recommend approval of modifications or waivers to existing agency policies as they pertain to NPOESS. The EXCOM will also review an annual business plan and approve the Convergence Master Plan (CMP) as defined in Section VII.

B. The Integrated Program Office

The IPO, under the direction and management of the SPD, will be the single functional entity responsible for the planning, budgeting, development, acquisition, launch, operation, and management of the NPOESS. The SPD is ultimately responsible to the triagency EXCOM for NPOESS. The SPD has decision authority for NPOESS matters, subject to the statutory authorities of the designated agencies, and reports to the NOAA Administrator, through the NOAA Assistant Administrator for the National Environmental Satellite, Data, and Information Service (AA NESDIS). Reporting through the AA NESDIS means that the SPD must have the concurrence of the AA NESDIS prior to the SPD making any NPOESS decisions affecting DOC/NOAA/NESDIS. The AA NESDIS has the lead within DOC for resolving issues that arise between the IPO and DOC/NOAA/NESDIS components prior to decisions being made that impact DOC/NOAA/NESDIS/NPOESS. Issues that cannot be resolved by the SPD and the AA NESDIS will be brought by them to the NOAA Administrator for resolution.

The IPO will be a separate entity located within the NESDIS, which is the organizational component in NOAA having responsibility for DOC satellite programs, and therefore, will provide the primary NOAA matrix support for the IPO. The AA NESDIS is responsible for all aspects of the current NOAA Polar-orbiting Operational Environmental Satellite (POES) program through the life of the N and N′ satellites to include coordinating POES fully with NPOESS. In addition, the AA NESDIS has the lead responsibility within the DOC/NOAA to ensure that the IPO and the NPOESS are properly supported and the NPOESS is properly integrated with the NOAA civil environmental satellite remote sensing mission.

The SPD will also coordinate decisions on NPOESS matters that affect DoD with the Assistant Secretary of the Air Force for Space (ASAF/SPACE) to ensure resolution of potential issues or forwarding of issues to the appropriate official for resolution. An NPOESS acquisition decisions made by the SPD that affect DoD will be coordinated with the - Air Force Service Acquisition Executive and any related issues resolved prior to decision execution.

During the transition to an operational NPOESS, the AA NESDIS and ASAF (Space), in consultation with the SPD, are responsible for coordinating and integrating the existing POES and DMSP activities with the NPOESS by promoting commonality, developing consistent budget submissions, and ensuring compatibility and interoperability. Further details regarding the relationship between the IPO/SPD and agency organizations/officials affected by or supporting the NPOESS will be described in the Convergence Master Plan.

The IPO shall consist of three functional line offices and an SPD staff operating under the management and direction of the SPD. Functions and responsibilities of the directors are as follows:

(1) The System Program Director (SPD) will:

(a) Direct the converged program and be responsible for financial, programmatic, and technical and operational performance of the NPOESS.

(b) Direct all IPO management functions, centrally control the distribution of all funds appropriated for or transferred to NPOESS and have or delegate final approval authority over all appropriate contract actions as defined in the CMP.

(c) Have final approval of the individuals nominated by the agencies for the positions of the Deputy System Program Director and the three Associate Directors (Acquisition, Technology Transition, and Operations).

(d) Be the Source Selection Advisory Council Chairman for NPOESS major component acquisition.

(e) Have primary responsibility on behalf of the EXCOM member agencies for all NPOESS-specific international agreements to include developing and negotiating terms and conditions to ensure compatibility with NPOESS goals and objectives. The SPD will participate in any activities resulting in U.S. national policy and/or U.S. Government international agreements that impact NPOESS.

(f) Prepare the NPOESS budget consistent with the agencies' internal budget processes. Execute the NPOESS budget in accordance with the approved program baseline.

(g) Participate in and coordinate on all interactions by the agencies with the Executive and Legislative branches regarding NPOESS.

(h) Develop the CMP and annual business plan.

(i) Propose, for EXCOM decision or recommendation, changes to agency policies or procedures as they pertain to the NPOESS.

(j) Approve all NPOESS acquisition documents prior to submission to the designated acquisition agency for action and approve of all acquisition/procurement decisions made below the EXCOM level prior to implementation.

(2) Associate Director for Acquisition (ADA) will:

(a) Be responsible to the SPD for developing, acquiring (including test and evaluation) and fielding the NPOESS components and for launch and early on-orbit checkout.

(b) Conduct developmental activities necessary to support the acquisition program baseline.

(c) Conduct, in concert with the Associate Director for Technology Transition (ADTT), studies to determine the potential impact upon system resources of accommodating new technologies being evaluated by the ADTT.

(d) Prepare the acquisition budget submissions for SPD approval.

(e) Prepare acquisition documents.

(f) Manage the acquisition budget as directed by the SPD.

(g) Ensure effective integrated logistics/life cycle support.

(h) Have final approval of the individual nominated for the position of Deputy ADA.

(3) The Associate Director for Technology Transition (ADTT) will:

(a) Be responsible to the SPD for promoting transition of new technologies that could cost effectively enhance the capability of NPOESS to meet operational requirements.

(b) Identify and evaluate new technologies which could be transitioned for further development by the ADA.

(c) Seek out, and provide to the ADA for evaluation, opportunities to fulfill operational requirements with flight-proven observation science/research instruments that may also simultaneously satisfy science requirements.

(d) Develop and update annually a strategic plan for technology transition to address unaccommodated Integrated Operational Requirements Document (IORD) requirements and enabling technologies

(e) Prepare the technology transition budget submission, based on the technology transition strategic plan, for SPD approval.

(f) Manage the technology transition budget as directed by the SPD.

(g) Have final approval of the individual nominated for the position of Deputy ADTT.

(4) The Associate Director for Operations (ADO) will:

(a) Be responsible to the SPD for operation of the NPOESS, which includes: commanding the spacecraft; recovering/analyzing health and status; acquiring telemetry data for trend analysis; ensuring communications for telemetry and tracking; providing a continuous sensor data stream, anomaly support, mission planning, and any necessary ground segment processing (as defined in the IORD) required to effectively interface with the users.

(b) Prepare the operations budget submissions for SPD approval.

(c) Manage the operations budget as directed by the SPD.

(d) Be the interface for operational activities with any international partners contributing to NPOESS in accordance with the appropriate international agreements.

(e) Have final approval of the individual nominated for the position of Deputy ADO.

(5) The SPD Staff will support the SPD in the areas of:

(a) Program Control, which will provide overall NPOESS programming, planning and budgeting functions.

(b) Systems Engineering, which provides system-level coordination of NPOESS engineering and integration activities, technical and cost feasibility analysis of IORD-defined user requirements, and documentation to support milestone decision activities.

(c) User Liaison, which will be the IPO interface for the primary civil and military users of NPOESS data to provide comments or concerns on the ability of NPOESS to meet requirements outlined in the IORD.

d) External Affairs, which will support the SPD by managing the development and coordination of activities to ensure the IPO effectively interacts with external (both domestic and international) organizations in fulfilling the SPD's responsibilities regarding the NPOESS.

V. AGENCY RESPONSIBILITIES

The lead agency will have the primary role in providing required support for the execution of a specific function under the management of the IPO. Lead agency in this agreement does not mean the total delegation of the activity to that single agency. The agency with the lead for a particular function will provide the Associate Director and core personnel as part of a triagency NPOESS team performing that function using appropriate agency policies, procedures and statutory authorities (with modifications recommended by the SPD to the proper authority or approved by the SPD as appropriate).

A. DoC Responsibilities:

The DOC, through NOAA, will have lead agency responsibility to the triagency Executive Committee (EXCOM) for the converged system. Specifically, NOAA will nominate the System Program Director (SPD), who will be approved by the EXCOM. NOAA will have lead agency responsibility to support the IPO for satellite and ground segment operations; and NOAA will have the lead responsibility for interfacing with national and international civil user communities, consistent with national security and foreign policy requirements. NOAA will also provide the Associate Director for Operations, the Deputy Associate Director for Acquisition, and sufficient personnel (as defined in the NPOESS staffing plan) to support each of the IPO's directorates and functions.

B. DoD Responsibilities:

The DoD will have lead agency responsibility to support the IPO in NPOESS component acquisitions necessary to execute the acquisition program baseline. Acquisition decisions made by the DoD EXCOM member affecting NPOESS will be undertaken with concurrence of the other EXCOM members. The statutory authorities resident within DoD for acquisition and contracting of the acquisition program baseline will be used to carry out this lead agency responsibility. Should other procurements be necessary to support the NPOESS, the SPD will decide how to carry them out, using the acquisition authority of the appropriate agency and will seek the approval of the EXCOM, if necessary. DoD will nominate the Deputy System Program Director and the Associate Director for Acquisition who will be approved by the SPD. DoD will also provide the Deputy Associate Director for Operations, Deputy Associate Director for Technology Transition and sufficient personnel (as defined in the NPOESS staffing plan) to support each of the IPO's directorates and functions. DoD will provide the majority of the acquisition personnel and acquisition infrastructure support to the IPO to include legal, contracting, administration, financial management, and logistics.

C. NASA Responsibilities:

NASA will have lead agency responsibility to support the IPO in facilitating the development and insertion of new cost-effective and enabling technologies that enhance the ability of the converged system to meet its operational requirements. In conjunction with the IPO, NASA will conduct periodic reviews of Mission to Planet Earth (MTPE) Projects to determine areas of common interest with the operational requirements and evaluate if and when these areas could be applied to the NPOESS. Also, in accordance with the conditions/principles specified in Appendix 1, NASA will supply additional copies of those NASA research instruments for flight on NPOESS. NASA will provide the Associate Director for Technology Transition who will be approved by the SPD. NASA will also provide sufficient personnel (as defined in the NPOESS staffing plan) to support each of the IPO's directorates and functions.

VI. REQUIREMENTS

An Integrated Operational Requirements Document (IORD) will be the sole operational requirements source from which triagency cost and technology assessments, specification development, and related acquisition activities will be conducted. The IORD shall be updated before each major milestone (see Figure 1). The assembling, evaluating and prioritizing of agency requirements to produce the IORD will be based on the DoD processes described in the 5000 series instructions, as tailored. The requirements process will be independent of the IPO and is designed to ensure each agency's requirements are accountable and traceable to each agency. To this end, each agency will designate a senior official to be its representative to the Joint Agency Requirements Council (JARC) and be accountable for its agency's requirements. Chairmanship of the JARC will rotate between DOC and DoD on a biannual basis. The JARC will resolve any interagency requirements issues. Appendix 2 provides further detail on the requirements process.

The agencies will establish a Senior User's Advisory Group (SUAG), independent of the IPO, representing the primary USG users of NPOESS data. This group will advise the SPD on the needs of the user community and on program decisions related to satisfaction of IORD requirements. This group will be small in number, and consist of at least the NOAA Assistant Administrator for Weather Services, NOAA Assistant Administrator for Satellite and Information Services, the Air Force Director of Weather, the Oceanographer of the Navy, Air Force Space Command Director of Operations, and the NASA Office for Mission to Planet Earth Science Division Director (if any NASA research instruments are used to meet operational requirements). Chairmanship of the SUAG will rotate between DOC and DoD on a bi-annual basis. A single agency will not chair both the SUAG and JARC simultaneously.

VII. NPOESS MANAGEMENT AND PROCESSES

NPOESS management and processes will be further defined and conducted in accordance with the Convergence Master Plan (CMP), which is to be developed by the SPD within 6 months of appointment. The CMP will be submitted to the EXCOM for unanimous approval. The CMP will contain: an Acquisition Management Plan; a Technology Transition Management Plan; an Operations Plan; a Funding Management Plan; and an integrated Organizational Management Plan. Sections VH. A. through E., below will be fully defined in the CMP. The SPD, in defining the processes, roles and responsibilities will ensure the key tenets derived from NSTC-2 and the Office of Science and Technology Policy Convergence Implementation Plan are adhered to.

The SPD will also develop an annual business plan and a long-range staffing plan. The business plan will address the primary goals and objectives for the year and lay out the principle milestones and the financial plan. It will also address issues to be resolved and the strategy for resolution. Other items will be included in the annual business plan as necessary (e.g., international cooperative efforts and NPOESS status). Building upon the FY 95 Triagency Staffing Plan, the SPD will develop, within 6 months of appointment, a long-range staffing plan for FY 96 and beyond. This long-range staffing plan will address the required number of personnel, appropriate personnel skill sets, grades and unique agency personnel certifications necessary to acquire, operate, or sustain the NPOESS throughout the system's life-cycle.

A. Acquisition Management Plan

OMB Circular A-109, DoDD 5000.1 and 5000.2 (as tailored) will form the basis of the NPOESS major system acquisition (see Figure 1), which will be carried out using DoD acquisition and contracting authority. The DoD component acquisition executive will be the NPOESS Source Selection Authority for NPOESS major component acquisitions. The agencies agree that the NPOESS acquisition is presently in Phase 0 with a Milestone I decision scheduled for approximately the fourth quarter FY 95/first quarter FY 96. An Acquisition Management Plan will be developed to explain the entire acquisition process from beginning to end and will:

– Address threat projections, life-cycle costs, integrated logistics support, cost-performance-schedule trade-offs, affordability constraints, and risk management at each milestone.

– Ensure acquisition strategies and program plans are appropriately tailored to accomplish program objectives and control risk.

– Ensure the acquisition process accommodates the triagency nature of the NPOESS.

– Ensure independent cost analyses are conducted using the structure of the Office of the Secretary of Defense Cost Analysis Improvement Group with NOAA and NASA membership.

B. Technology Transition Management Plan

The NPOESS technology transition management plan will identify and promote processes to foster development of promising new technologies which will enable new operational capabilities as defined in the IORD or enhance existing operational capabilities as delineated in the IORD. The technology transition management plan will be defined in detail in the CMP and developed in accordance with the following guidelines:

– The office will promote relationships among industry, academia and Government organizations to ensure the IPO reaps maximum benefit from ongoing developments and will promote new developments where it is deemed beneficial or necessary to satisfy objective IORD requirements.

– The office will promote the infusion of new technology into NPOESS to advance its capability to meet user requirements. The office will monitor research activities of various organizations (NASA, DoD, universities, etc.) for applicability and, where warranted, will recommend and conduct further study and/or demonstrations with SPD approval and funding by the IPO.

C. Operations Plan

The NPOESS will be operated to ensure data are supplied to the NPOESS users for further specialized data processing as stated in the IORD. The SPD will develop an operations concept. The operations concept and any required implementing documentation will be submitted to the EXCOM for approval as part of the CMP. NPOESS matters not under their authority (e.g., military operations) will be forwarded to the proper authorities for action/approval as agreed upon by the EXCOM. The operations concept will address day-to-day operations of the NPOESS, including the development of user interfaces and analysis of data to ensure the converged system is capable of meeting its performance requirements . The operations concept will specifically address Command, Control, and Communications (C3) operations (to include any agreements needed to implement changes in C3 authorities and responsibilities as necessary during times of crisis or war). ‘The operations concept will also reflect the NPOESS launch-on-failure, or anticipated failure, policy needed to maintain uninterrupted availability of critical data. The operations concept will address data retrieval, ground preprocessing, distribution, launch call procedures, transition from early on-orbit checkout to operational status, and any modification to standard operating procedures which may be needed. The operations concept will ensure:

– The NPOESS will establish a civilian interface to national and international civil users to promote its open character.

– The NPOESS will be able to implement data denial should the Secretary of Defense (SECDEF) direct, after consulting with the Secretaries of Commerce (SECCOM) and State (SECSTATE). In that regard, the operations concept will specifically address the process for consultation between SECDEF, SECCOM, and SECSTATE and the implementing process at the ground site(s) and the timeliness In the event that a foreign satellite is part of NPOESS, the operations concept will also include the details of data denial implementation of any U.S. instruments on a foreign satellite (e.g., EUMETSAT’s METOP series) in accordance with applicable agreements.

– NOAA, through NESDIS, will provide the primary Satellite Operations Center (SOC) infrastructure.

– DoD will provide a mission capable backup SOC at Falcon AFB, Colorado.

– NOAA Command and Data Acquisition stations and elements of the USAF Satellite Control Network (AFSCN), as appropriate, will be utilized to provide C3 and mission data recovery support for NPOESS and the primary and backup SOCs.

Further, the IPO will develop and present a plan to the EXCOM for the early transition to a joint agency C3 architecture. This will enable transition of the operation of the current POES and DMSP satellites to the IPO as soon as practical. This transition is envisioned to occur in the 1998 time frame to coincide with the DoD's original plans to close dedicated DMSP command and control sites at Fairchild and Offutt APBs. The USG role in the C3 of the METOP system (space and ground segment) will be included. Furthermore, operation of the current POES and DMSP satellites will be transitioned to the IPO as soon as practical. The NOAA SOC will be used for C3.

D. Funding Management Plan

The process used to fund NPOESS (to include the process for ensuring appropriated funding flows to the IPO) will be defined in detail in the CMP and will contain the following key tenets:

– Each agency's funding will be based on total program cost and common and unique requirements. Since NASA is not an operational agency, the NASA contribution will be limited to funding as specified in Appendix 1.

– A 50/50 cost sharing approach is used for all near-term common activities—the agreed upon DoD and DOC FY 96-01 funding profiles are contained in Figure 2.

– The IPO will budget funds to be applied to technology efforts in support of the technology transition strategic plan.

– Unique agency requirements specified in the IORD will be funded by the appropriate agency.

– For common data products, if an agency's more stringent requirements are determined to be a significant cost driver, then the additional funds required will be provided by this agency.

– All impacts to NPOESS to accommodate payloads which do not satisfy IORD requirements will be funded by the requesting agency.

– Cost sharing will be reassessed, at a minimum, prior to each acquisition milestone review.

E. Organizational Management Plan

Organizational management for the NPOESS will be addressed in the CMP and will include:

– The relationship between the IPO and the requirements process and requirements organizations.

– The relationship between the IPO and any external organization which provides primary support to the IPO (e.g., NESDIS, Air Force, Navy). The SPD will decide to what extent specific functions will be performed by the IPO or will be matrixed from agency offices external to the IPO, taking into account existing agency capabilities and the triagency nature of the NPOESS.

– The processes for personnel management to include performance reporting and succession planning.

– Security classification guidance for the NPOESS program, to include which classification authorities and procedures will be used.

VIII. EFFECTIVE DATE/AMENDMENT/TERMINATION

This agreement shall become effective when it has been signed on behalf of the three signatory agencies.

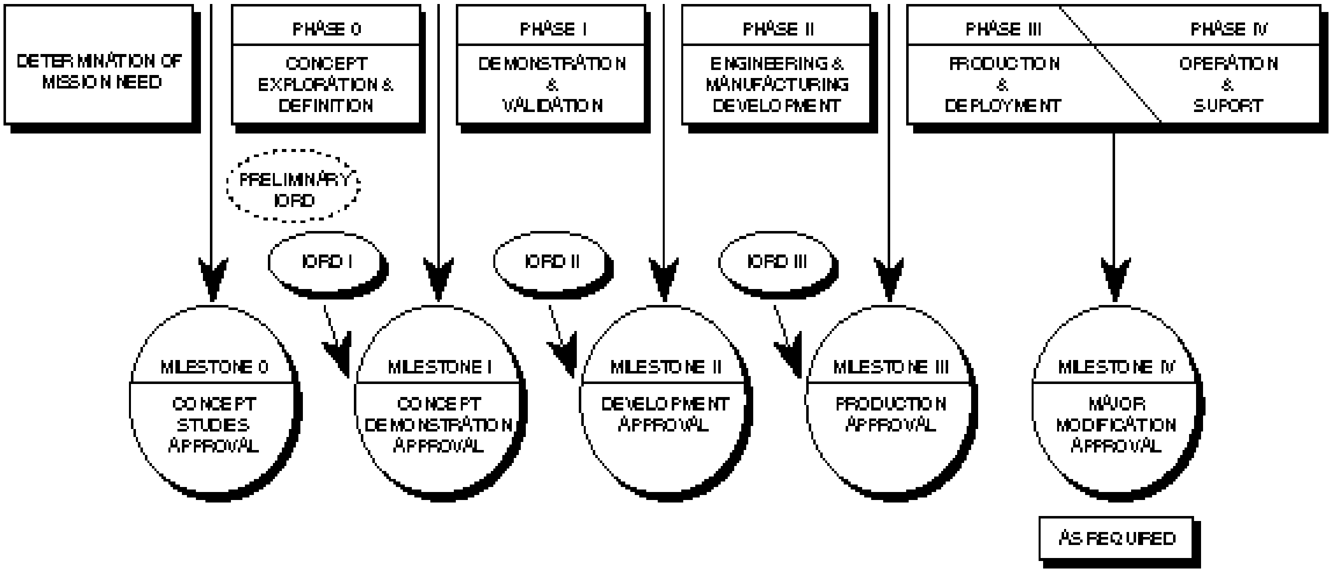
A review of this Memorandum of Agreement will occur within 3 years and on a 4-year cycle thereafter by an EXCOM approved committee. A specific topic to be addressed during the initial review will be the relationship of the IPO and the SPD to the NOAA organizational structure with particular attention to NESDIS and the relationship of the SPD to the NESDIS AA.

This MOA may be amended/terminated at any time by the mutual written consent of the parties hereto. Any party may terminate this agreement by giving at least 6 months prior notification to the other parties. Should it be necessary to terminate the agreement, appropriate notification will be made to the White House and the relevant Congressional committees.

ORIGINAL SIGNED BY **Secretary of Commerce**	**ORIGINAL SIGNED BY** **Secretary of Defense**	**ORIGINAL SIGNED BY** **NASA Administrator**

Figure 1

Acquisition Milestones & Phases



Note: The NPOESS Acquisition will follow the DoD acquisition (as tailored) and terminology

Figure 2

Budget & Agency Contributions

	FY96	FY97	FY98	FY99	FYOO	FYO1	TOTAL
BUDGET	78.0	120.0	187.0	340.2	372.7	328.1	1426.0
DOC	54.0	78.2	131.4	146.5	162.5	140.4	713.0
DOD	24.0	41.8	55.6	193.7	210.2	187.7	713.0

- FY95 IPO BUDGET IS 23.6 M (DOC 16.0M/DoD 7.6 M)
- AGENCIES AGREED TO 50/50 SPLIT OVER FYDP
- BUDGET FIGURES WILL BE REFINED AFTER PHASE 0 STUDIES

Appendix 1
to
NPOESS MOA

CONDITIONS FOR SUPPLYING NASA RESEARCH INSTRUMENTS TO THE CONVERGENCE OPERATIONAL (NPOESS) PLATFORM

If the decision is made to fly a NASA instrument on the (NPOESS) platform instead of continuing to fly it on a NASA research spacecraft, because the research instrument will meet the convergence operational requirements in a cost-effective manner and continues to provide data so as to fulfill primary NASA research mission requirements, NASA will provide additional copy(s) of the instrument for flight on the NPOESS platform at no unit cost to the NPOESS program. This policy of supplying instruments at no cost will apply as long as NASA continues to need the data supplied by the instrument to fulfill its primary research mission objectives. As part of the transfer of the NASA instrument to the NPOESS platform, the NASA scientific research requirements associated with that instrument will likewise be included in their entirety in the formal set of operational program requirements listed in the Integrated Operational Requirements Document (IORD; possibly as an annex) and removed from the IORD when the NASA instrument no longer flies on the NPOESS. Modifications to an instrument will only be considered if there is no loss of NASA science. The cost sharing by the three agencies for modification and/or accommodation of the NASA research instrument will be agreed upon by the agencies as part of the decision to fly the instrument on the NPOESS platform(s).

The term "NASA research instrument" refers to those NASA instruments which have been developed and flown in space to provide data that are necessary to fulfill NASA scientific research objectives (e.g., provide data to answer questions regarding global change as defined by the Intergovemmental Panel on Climate Change (IPCC) and incorporated in NASA's research program objectives).

Appendix 2
to
NPOESS MOA

REQUIREMENTS PROCESS

An Integrated Operational Requirements Document (IORD) will be the sole operational requirements source from which triagency cost and technology assessments, specification development, and related acquisition activities will be conducted. The requirements process will be independent of the IPO and is designed to ensure each agency's requirements are accountable and traceable to each agency. Two distinct bodies have direct responsibility for the development and approval of the NPOESS IORD. These bodies are the Joint Agency Requirements Group (JARG) and the Joint Agency Requirements Council (JARC).

The JARG is the interagency group responsible for developing the NPOESS IORD and administering the IORD approval process. JARG members representing triagency requirements will come from HQ Air Force Space Command, Office of the Oceanographer of the Navy, Air Force Directorate of Weather, NOAA/ National Environmental Satellite, Data, and Information Service (NESDIS), NASA Goddard Space Flight Center (GSFC), National Weather Service (NWS), the Office of Oceanic and Atmospheric Research (OAR), National Ocean Service (NOS), National Marine Fisheries Service (NMFS) and the NASA Office for Mission to Planet Earth (MTPE). Additional JARG membership will come from Air Force, Navy, Army, NOAA and NASA, as required. The HQ Air Force Space Command, NOAA/NESDIS and NASA/GSFC will be the JARG points-of-contact responsible for administrative support associated with the IORD. Through Tri-Agency IORD development, the JARG will: harmonize and document similar interagency operational requirements; identify and document agency-unique operational requirements; document requirements issues (if any); prepare the IORD for JARC approval and document for JARC decisions any requirements issues. The JARG will then release the draft NPOESS IORD for appropriate agency review/comment. The JARG will resolve draft comments and develop the final IORD for release to all agencies for review/ approval. The final IORD will be staffed through each agency's IORD approval authority. The JARG will also develop a requirements master plan for JARC approval which details the process necessary to execute this appendix. DoD policies and procedures are the basis for this requirements process. NASA science requirements will be included in the IORD as stated in Appendix I to this MOA. The JARG will be chaired on a rotating (biennial) basis between DOC and DoD. The chair is responsible for all JARG administration.

The JARC is the senior interagency body responsible to approve the NPOESS IORD. The JARC will resolve all JARG documented interagency requirements issues not solvable at a lower level. JARC membership will consist of the Vice Chairman of the Joint Chiefs of Staff for DoD, the Deputy Under Secretary of Commerce for Oceans and Atmosphere, and the Associate Administrator for Mission to Planet Earth for NASA. In addition, other agency representatives may attend the JARC meeting as required. After JARC approval, the IORD will be forwarded to the EXCOM for endorsement.

APPENDIX **F-2**

THE WHITE HOUSE
WASHINGTON

May 15, 1995

PRESIDENTIAL REVIEW DIRECTIVE/NSTC-2

MEMORANDUM FOR THE VICE PRESIDENT
THE SECRETARY OF STATE
THE SECRETARY OF TREASURY
THE SECRETARY OF DEFENSE
THE SECRETARY OF INTERIOR
THE SECRETARY OF AGRICULTURE
THE SECRETARY OF COMMERCE
THE SECRETARY OF LABOR
THE SECRETARY OF HEALTH AND HUMAN SERVICES
THE SECRETARY OF TRANSPORTATION
THE SECRETARY OF ENERGY
THE SECRETARY OF EDUCATION
THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY
THE UNITED STATES TRADE REPRESENTATIVE
THE DIRECTOR OF THE OFFICE OF MANAGEMENT AND BUDGET
THE ASSISTANT TO THE PRESIDENT FOR DOMESTIC POLICY
THE ASSISTANT TO THE PRESIDENT FOR ECONOMIC POLICY
THE DIRECTOR OF CENTRAL INTELLIGENCE
THE DIRECTOR OF THE ARMS CONTROL AND DISARMAMENT AGENCY
THE CHAIRMAN OF THE JOINT CHIEFS OF STAFF
THE ADMINISTRATOR OF THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
THE DIRECTOR OF THE NATIONAL SCIENCE FOUNDATION
THE DIRECTOR OF THE NATIONAL INSTITUTES OF HEALTH

SUBJECT: Interagency Space Policy Review

Pursuant to the November 23, 1993, Executive Order issued by the President establishing the National Science and Technology Council, the NSTC is charged with overseeing, the duties of the National Space Council. Prior to the establishment of the NSTC, a number of National Space Policy Directives (NSPDs) were developed through the National Space Council. These NSPDs contain national policy, guidelines and implementing actions with respect to the conduct of the United States space programs and related activities. In addition to these NSPDs, there are several national security directives which contain policy guidance related to space.

Given the changes that have taken place in our domestic and international space policy, and in light of Presidential directives signed by President Clinton (NSTC/PDD-2, NSTC/PDD-3, NSTC/PDD-4), it is appropriate to undertake a comprehensive review of our national space policy. The Office of Science and Technology Policy and the National Security Council will therefore co-chair an Interagency Working Group to review the following National Space Council Policy Directives:

National Space Policy Directive 1—National Space Policy (November 2, 1989)
National Space Policy Directive 2—Commercial Space Launch Policy (September 5, 1990)
National Space Policy Directive 3—U.S. Commercial Space Launch Policy Guidelines (February 12, 1991)
National Space Policy Directive 4—National Space Launch Strategy (July 24, 1991)
National Space Policy Directive 5—Landsat Remote Sensing Strategy (February 2, 1992)
National Space Policy Directive 6—Space Exploration Initiative Strategy (March 13, 1992)
National Space Policy Directive 7—Space-based Global Change Observation (May, 28 1992)

The Interagency Working Group will also review related national security directives as appropriate.

Guidelines for the Review

An Interagency Working Group (IWG) will be established to conduct the review. The IWG will be co-chaired by OSTP and NSC and will include the participation of the agencies and departments listed as distribution on this review directive. The co-chairs may invite other agencies to participate as appropriate and may delegate work to be completed under this directive to special working groups or sub-groups of the IWG.

External Advice

The interagency working group may also seek advice from members of the President's Committee of Advisors on Science and Technology and other appropriate representatives of industry, academia, the nonprofit sector and state and local governments in conducting this review.

Scope of the Review

The review will:

1. Identify and recommend changes to portions of NSPD-1 that are factually incorrect or out of date.

2. Identify and recommend changes to NSPD-1 that are required in order to align NSPD-1 with space policy established in NSTC-2 (Landsat Remote Sensing), NSTC-3 (Convergence of DoD/NOAA polar orbiting weather satellites) and NSTC-4(National Space Transportation Policy).

3. Identify and recommend other appropriate changes to NSPD-1 to reflect the Administration's civilian, national security and commercial space policy.

4. Provide recommendations on elimination and/or consolidation of NPSD-2, NSPD-3, NSPD-4, NSPD-5, NSPD-6 and NSPD-7.

5. Identify and recommend appropriate changes to related national security directives containing guidance on space policies and programs.

Timing

Recommendations resulting from this review will be provided to the Assistant to the President for Science and Technology and the Assistant to the President for National Security Affairs no later than November 1, 1995.

ORIGINAL SIGNED BY
John H. Gibbons
Assistant to the President for
Science and Technology

ORIGINAL SIGNED BY
Anthony Lake
Assistant to the President for
National Security Affairs

GLOSSARY

AAS Advanced Automated System (program) (FAA)

ACDA Arms Control and Disarmament Agency

ACO Advanced Concepts Office (NASA)

ACTS Advanced Communications Technology Satellite

ADEOS (Japanese) Advanced Earth Observing Satellite

AEB Brazilian space agency

ADS-B Automatic Dependent Surveillance–Broadcast

AGO Automatic Geophysical Observatory

AIDS Acquired Immune Deficiency Syndrome

AMOS Air Force Maui Optical System

anechoic Neither having nor producing an echo angle of attack. The acute angle of attack between the chord of an airfoil and its direction of motion relative to the air, often referred to as "alpha"; when an airfoil's exceeds the one that provides maximum lift, it goes into a stall, losing air speed and, potentially, the capability of the pilot to control the airplane.

ARC Ames Research Center (NASA)

ARPA Advanced Research Projects Agency (formerly Defense Advanced Research Project Agency)

ARS Agricultural Research Service (USDA)

ASRM Advanced Solid Rocket Motor

ASTP Apollo-Soyuz Test Project

Astro Astronomy Observatory

astronomical unit A measure for distances in space, equal to the mean distance of the Earth from the Sun—that is, 93,000,000 miles (149,599,000 kilometers)

ATLAS Atmospheric Laboratory for Applications and Science

ATV Automated Transfer Vehicle

AVHRR Advanced Very High Resolution Radiometer

AVIRIS Airborne Visible and Infrared Imaging Spectrometer

AXAF Advanced X-ray Astrophysics Facility

BIA Bureau of Indian Affairs (DoI)

bioreactor An advanced tissue culturing 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

BMDO Ballistic Missile Defense Organization (formerly SDIO)

boreal Northern

boundary layer A layer of fluid, close to the surface of a body placed in a moving stream, that is distinguishable from the main airflow by distinctive flow characteristics of its own caused by friction

CAN Cooperative Agreement Notice

canard An aircraft or aircraft configuration having its horizontal stabilizing and control surfaces in front of the wing or wings

CARA Center for Astrophysical Research in Antarctica (NSF)

carbon-carbon In one application, an improved form of disk brakes featuring carbon rotors and carbon stators in place of the beryllium formerly used

CAS Computational AeroSciences

Cassini A Saturn orbiter/Titan probe

Category I An aircraft approach procedure that provides for approach to a height above touchdown of no less than 200 feet and with runway visual range of no less than 1,800 feet

Category II An aircraft approach procedure with a height no less than 100 feet and visual range no less than 1,200 feet

Category III An aircraft approach procedure involving no minimal decision height and three different minimal visual ranges—at least 700 feet for IIIA, 150 feet for IIIB, and no minimum visual range for IIIC

CD–ROM Compact Disk–Read Only Memory

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act

CFC Chlorofluorocarbon

CGRO Compton Gamma Ray Observatory

CIS Commonwealth of Independent States, a grouping of independent states formerly part of the Soviet Union

cm centimeter

CMB Cosmic Microwave Background (Anistrophy)

CNES Centre National d'Etudes Spatiales—the French space agency

COBE Cosmic Background Explorer

Comsat Communications Satellite Corporation

COPUOS Committee on the Peaceful Uses of Outer Space (United Nations)

corona The outer atmosphere of the Sun, extending about a million miles above the surface

cosmic rays Not forms of energy, such as x-rays or gamma rays, but particles of matter

Cospas Russian acronym meaning Space System for Search of Vessels in Distress

CRISTA-SPAS Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite

CRRES Combined Release and Radiation Effects Satellite

CSA Canadian Space Agency

cryogenic Very low in temperature

CTAS Center-TRACON Automation System

C3I Command, control, communications, and intelligence (DoD)

DAAC Distributed Active Archive Center

DARPA See ARPA

DARS Digital Audio Radio Services

dB Decibel

DBS Direct Broadcast Satellite

DC-X Delta Clipper–Experimental

DC-XA Delta Clipper–Experimental Advanced

DFRC Dryden Flight Research Center (NASA)

DMSP Defense Meteorological Satellite Program—DoD's polar orbiting weather satellite system

DoC Department of Commerce

DoD Department of Defense

DoE Department of Energy

DoI Department of the Interior

DOLILU Day-of-Launch I-Load Update (System)

DoS Department of State

DoT Department of Transportation

drag The force, produced by friction, that impedes a body's motion through a fluid

DSCS Defense Satellite Communication System

DSP Defense Support Program

EA Environmental assessment

EAFB Edwards Air Force Base

EELV Evolved Expendable Launch Vehicle

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, and infrared waves, to radio waves at the long-waved end of the spectrum

El Niño A warm inshore current annually flowing south along the coast of Ecuador around the end of December and extending about every 7 to 10 years down the coast of Peru

ELV Expendable Launch Vehicle

enthalpy The heat content of a system undergoing change

envelope The operational parameters within which an aircraft can fly

EOS Earth Observing System—a series of satellites, part of NASA's Mission to Planet Earth, being designed for launch at the end of the 1990's to gather data on global change

EOSAT Earth Observation Satellite Company

EOSDIS EOS Data and Information System

EPA Environmental Protection Agency

EROS Earth Resources Observation System

ERS European Remote Sensing Satellite

ERTS Earth Resources Technology Satellite (known as Landsat)

ESA European Space Agency

EUMETSAT European Organisation for the Exploitation of Meteorological Satellites

EVA Extravehicular activity

F Fahrenheit

FAA Federal Aviation Administration

faculae Bright areas visible on the surface of the Sun, especially near its edge

FAR Federal Acquisition Regulations

FBL Fly-by-light (avionics system)

FAS Foreign Agricultural Service (USDA)

FCC Federal Communications Commission

FEMA Federal Emergency Management Agency

FGB Functional Cargo Block (for the International Space Station; acronym is from the Russian term)

fly-by-light The use of light signals to connect the pilot's control devices with the aircraft control surfaces; or the use of light (fiber optic) control connections with no mechanical backup linkages and providing the pilot direct control of aircraft motion rather than control surface position

fly-by-wire The use of electrical signals to connect the pilot's control devices with the aircraft control surfaces; or the use of electrical control connections with no mechanical backup linkages and providing the pilot direct control of aircraft motion rather than control surface position

FWS (U.S.) Fish and Wildlife Service (DoI)

FY Fiscal year

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

Galactic Halo An enigmatic distribution of older stars that appears key to understanding the formation of our galaxy

gamma rays The shortest of electromagnetic radiations, emitted by some radioactive substances

GATT General Agreement on Tariffs and Trade

GBS Global Broadcast Service

GEO Geosynchronous Earth orbit

Geosat Geodetic and Geophysical Satellite

geostationary Traveling about the Earth's equator at an altitude of at least 35,000 kilometers and at a speed matching that of the Earth's rotation, thereby maintaining a constant relation to points on the Earth

geosynchronous geostationary

GGS Global Geospace Science (program)

GII Global Information Infrastructure

GIS Geographic Information System

GLOBE Global Learning and Observations to Benefit the Environment (program)

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

GM General Motors (Corporation)

GMT Greenwich Mean Time

GOES Geostationary Operational Environmental Satellite

GPHS General Purpose Heat Source

GPS Global Positioning System

GPS-MET GPS-Meteorological (experiment)

ground effect The temporary gain in lift during flight at very low altitudes caused by the compression of the air between the wings of an airplane and the ground

GSFC Goddard Space Flight Center (NASA)

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

heliosphere The region of the Sun's influence, including the Sun and the interplanetary medium

high-alpha High angle of attack

high-bypass engine A turbo-engine having a bypass ratio of more than four to one, the bypass ratio being the proportion of air that flows through the engine outside the inner case to that which flows inside that case

HIV Human immunodeficiency virus

HPCC High Performance Computing and Communications

HSCT High-Speed Civil Transport

HSR High-Speed Research (program)

HST Hubble Space Telescope

HT/MT Heavy Terminal/Medium Terminal (program)

hypersonic Faster than Mach 4; faster than "high speed"

hyper-spectral Having many very narrow frequency bands (1,000 or more), enabling a satellite to monitor specific sites instead of wide swaths

IEOS International Earth Observing System

IITA Information Infrastructure Technology and Applications (component of HPCC)

INMARSAT International Mobile (formerly Maritime) Satellite Organization

Integrated modular avionics Aircraft-unique avionics cabinet that replaces multiple black boxes with shared common equipment and generic software

INTELSAT International Telecommunications Satellite (Organization)

interferometry The production and measurement of interference from two or more coherent wave trains emitted from the same source

Internet An international computer network that began about 1970 as the NSF Net; very slowly it became a collection of more than 40,000 independently managed computer networks worldwide that have adopted common protocols to permit exchange of electronic information

ionosphere That region of the Earth's atmosphere so named because of the presence of ionized atoms in layers that reflect radio waves and short-wave transmissions

IORD Integrated Operational Requirements Document

IPCC International Panel on Climate Change

IRS-1B Indian Remote Sensing–1B (satellite)

ISO International Organization for Standardization

ISS International Space Station

ISTP International Solar Terrestrial Physics Program

ITU International Telecommunications Union; an intergovernmental organization founded in 1865 that became a specialized agency of the United Nations in 1947

ITWS Integrated Terminal Weather System

IUS Inertial Upper Stage

IV&V Independent validation and verification

JAST Joint Advanced Strike Technology (program) (DoD)

JCIC Joint Compliance and Inspection Commission (START)

JPL Jet Propulsion Laboratory (NASA)

JSC Johnson Space Center (NASA)

K-band Radio frequencies in the 20-gigahertz range

Ka-band A radio frequency in the 30-gigahertz range

KAO Kuiper Airborne Observatory

Kelvin Temperature scale in which absolute zero is 0° and water freezes at 273.16°

km Kilometer

KSC Kennedy Space Center (NASA)

Ku-band Radio frequencies in the 11-12 gigaherz range

Kuiper Airborne Observatory A NASA C-141 aircraft equipped with a 0.97-meter telescope

LACE Low-powered Atmosphere Compensation Experiment (DoD)

laminar Of fluid flow, smooth, as contrasted with turbulent; not characterized by crossflow of fluid particles

Landsat Land [remote sensing] Satellite; also known as ERTS, a series of satellites designed to collect information about the Earth's natural resources

LaRC Langley Research Center (NASA)

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

LEO Low-Earth orbit (100 to 350 nautical miles above the Earth)

LeRC Lewis Research Center (NASA)

Lidar Light radar

LIDAR Light Intersection Direction and Ranging

lift The force exerted on an airfoil, such as a wing by a flow of air over and around it, causing it to rise perpendicularly to the direction of flight

LISS Linear Imaging Self-Scanning Sensor

low-Earth orbit An orbit of the Earth approximately 100 to 350 nautical miles above its surface

LOX Liquid oxygen

LWIR Long-Wavelength Infrared

LWRHU Lightweight Radioisotope Heater Unit

m Meter

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 degrees Fahrenheit and at sea level, for example, Mach 1=approximately 741 mph or 1,192 kilometers per hour

Mach See M

Magellanic Stream A large filament of neutral hydrogen gas from the Milky Way's radio emission that originates at the Small Magellanic Cloud, a Milky Way satellite dwarf galaxy, and extends almost one-third of the way around the sky

magnetosphere The region of the Earth's atmosphere where ionized gas plays an important role in the atmospheric dynamics and where consequently, the geomagnetic field also exerts an important influence; other magnetic planets, such as Jupiter, have magnetospheres that are similar in many respects to the Earth's

maser Microwave Amplification by Simulated Emission of Radiation—a device introduced in 1953 with multiple applications in physics, chemistry, and radio and television communication

mesopause The layer of the Earth's atmosphere with the lowest temperature, from 50 to 53 miles (80 to 85 kilometers) up

mesosphere That portion of the Earth's atmosphere located 34 to 50 miles (55 to 80 kilometers) up, where temperature decreases with increasing altitude

METEOR Multiple Experiment to Earth Orbit and Return (program)

MinSci (Russian) Ministry of Science and Technology Policy

MMU Manned Maneuvering Unit

Mode C transponder A radar beacon receiver/transponder capable of reporting the attitude of the aircraft aboard which it is installed

MOU Memorandum of Understanding

MSS Multispectral Scanner

MTCR Missile Technology Control Regime

MTPE 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 on it

NAPP National Aerial Photography Program

NASA National Aeronautics and Space Administration

NASCOM NASA Communications (network)

NASDA (Japanese) National Space Development Agency

NASS National Agricultural Statistics Service (USDA)

NATO North Atlantic Treaty Organization

NBS National Biological Service (DoI)

NCAR National Center for Atmospheric Research

NCDC National Climatic Data Center (NOAA)

NCI National Cancer Institute (NIH)

NERL National Exposure Research Laboratory (EPA)

NESDIS National Environmental Satellite, Data, and Information Service (NOAA)

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 (NOAA)

NIH National Institutes of Health

NIMS Near-Infrared Mapping Spectrometer

NIST National Institute of Standards and Technology (DoC)

NOAA National Oceanic and Atmospheric Administration (DoC); also the designation of that administration's Sun-synchronous satellites in polar orbit

nominal Functioning as designed

NPOESS National Polar-orbiting Operational Environmental Satellite System

NPS National Park Service (DoI)

NRCS National Resources Conservation Service (formerly Soil Conservation Service) (USDA)

NRL Naval Research Laboratory

NSAU National Space Agency of Ukraine

NSC National Security Council

NSF National Science Foundation

NSORS NOAA Satellite Ocean Remote Sensing (program)

NSPD National Space Policy Directive

NSTC National Science and Technology Council

NTIA National Telecommunications and Information Administration (DoC); the Federal Government's radio spectrum manager, which coordinates the use of LEO satellite networks, such as those for Landsat, Navstar GPS, the Space Shuttle, and TIROS, with other countries of the world

NWTC National Wind Tunnel Complex

OASC Office of Air and Space Commercialization (DoC)

OCST Office of Commercial Space Transportation (DoT)

ODERACS Orbital Debris Radar Calibration Spheres (payload)

OLMSA Office of Life and Microgravity Sciences and Applications (NASA)

on-orbit In orbit

order of magnitude An amount equal to ten times a given value; thus if some quantity was ten times as great as another quantity, it would be an order of magnitude greater; if one hundred times as great, it would be larger by two orders of magnitude

OSTP Office of Science and Technology Policy (White House)

OTD Optical Transient Detector

Pathfinder A program that focuses on the processing, reprocessing, maintenance, archiving, and distribution of existing Earth science data sets to make them more useful to researchers; NASA, NOAA, and USGS are involved in specific Pathfinder efforts

PBW Power-by-wire (avionics system)

PCA Propulsion Controlled Aircraft

PEACESAT Pan-Pacific Education and Communication Experiments by Satellite

petrology The science that deals with the origin, history, occurrence, structure, and chemical classification of rocks

photogrammetry The process of surveying, as in map making, by taking aerial photographs

piezoelectricity The property exhibited by some asymmetrical crystalline materials that, when subjected to strain in suitable directions, develop polarization proportional to the strain

pixels Short for "picture elements," which provide image resolution in vidicon-type detectors plage; bright, granular areas in the chromosphere of the Sun

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

POAM Polar Ozone and Aerosol Measurement (experiment)

POES Polar-orbiting Operational Environmental Satellite (program)

polar orbit The path of an Earth satellite that passes near or over the North and South Poles

power-by-wire The use of electrical power, in place of hydraulics, to move the control surfaces of an aircraft via electromechanical actuators

PPS Precise Positioning Service

Pu-238 A specific 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 together; pulsars emit extremely regular pulses of radio waves

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

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

RCRA Resource Conservation and Recovery Act

real-time Immediate, as an event is occurring

red shift Shift of spectral lines toward the red end of the spectrum, indicating motion away from the observer in the lines of sight

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

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

RFP Request for Proposals

RHU Radioisotope Heater Unit

RLV Reusable Launch Vehicle

RME Relay Mirror Experiment (satellite) (DoD)

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

RSA Russian Space Agency

RTG Radioisotope Thermoelectric Generator

s second

SABER Situational Awareness Beacon with Reply (system) (Navy)

SAMPEX Solar, Anomalous, and Magnetospheric Particle Explorer

SAO Smithsonian Astrophysical Observatory

SAR Synthetic Aperture Radar

Sarsat Search and Rescue Satellite-Aided Tracking System

SBUV Solar Backscatter Ultraviolet (spectral radiometer)

scramjet Supersonic-combustion ramjet

SDIO Strategic Defense Initiative Organization; see BMDO

SLS Spacelab Life Sciences (payload)

SLV Space Launch Vehicle

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

SPARTAN Shuttle Pointed Autonomous Research Tool for Astronomy

SPAS Shuttle Pallet Satellite

SPOT Satellite Pour l'Observation de la Terre (French satellite for the observation of the Earth)

squitter Transmitter for aircraft navigation and traffic control signals

SR&QA Safety, reliability, and quality assurance

SRL Space Radar Laboratory

SSBUV Shuttle Solar Backscatter Ultraviolet (spectrometer)

SSCE Solid Surface Combustion Experiment

SSME Space Shuttle Main Engine

SSTO Single-stage-to-orbit

STAC (Russian) Science and Technical Advisory Council

stall A loss of lift by an aircraft or airfoil resulting from insufficient air speed or excessive angle of attack

START Strategic Arms Reduction Treaty

STEP Space Test Experiments Platform

Stirling engine or generator One in which work is performed by the expansion of gas at high temperature to which heat is supplied through a wall

STOL Short Takeoff and Landing

STOVL Short Takeoff and Vertical Landing (aircraft)

stratosphere The atmospheric zone 12 to 31 miles (20 to 50 kilometers) up, exhibiting increased temperature with increased altitude

STRV Spsce Technology Research Vehicle

STS Space Transportation System

STSC Scientific and Technical Subcommittee (of COPUOS)

sunspot A vortex of gas on the surface of the Sun associated with stray local magnetic activity

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) that exhibits a luminosity ranging from 10 million to 100 million times that of our Sun

TATCA Terminal Air Traffic Control Automation (program)

TCAS Traffic alert and Collision Avoidance System

TDRS Tracking and Data Relay Satellite

teraFLOPS 10^{12} floating point operations per second

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

thermosphere The atmospheric zone beginning about 53 miles (85 kilometers) up and characterized by a significant rise in temperature with increased altitude

thrust-vectoring system A system on a jet engine to vary the direction of its exhaust nozzles to change the direction of the thrust

TIROS Television and Infrared Operational Satellite

TM (Landsat) Thematic Mapper (instrument)

TOPEX/Poseidon Ocean Topography Experiment

torus A doughnut-shaped figure

TOS Transfer Orbit Stage

TOVS TIROS Operational Vertical Sounder

TPFO TOPEX/Poseidon Follow-On

TRACON Terminal radar control

troposphere That portion of the atmosphere about 7 to 10 miles (11 to 16 kilometers) up where clouds form and convection is active

TRMM Tropical Rainfall Measuring Mission

UAH University of Alabama at Huntsville

UARS Upper Atmosphere Research Satellite

UAV Unmanned Aerial Vehicle

UFO UHF Follow-On

UHF Ultra High Frequency; any frequency between 300 and 3,000 megacycles per second

UHT Ukrainian Universal Hand Tool

U.K. United Kingdom of Great Britain and Northern Ireland

UN United Nations

UNSCOM United Nations Special Commission (on Iraq)

U.S. United States

USDA U.S. Department of Agriculture

USD (A&T) Undersecretary of Defense for Acquisition and Technology

USGCRP U.S. Global Change Research Program

USGS U.S. Geological Survey (DoI)

USIA U.S. Information Agency

USML U.S. Microgravity Laboratory

USTR U.S. Trade Representative

UV Ultraviolet

UVCS Ultraviolet Coronal Spectrometer

VAFB Vandenberg Air Force Base

VHF Very High Frequency; any radio frequency between 30 and 300 megacycles per second

viscosity Resistance to flow or change of shape under pressure

VLBA Very Long Baseline Array; a set of 10 radio telescopes in the continental United States, Hawaii, and St. Croix

VOA Voice of America

vortices Circular patterns of air created from lift generated by the wings (or rotor) of an aircraft or helicopter; the vortices from one aircraft may pose a hazard to following aircraft

VSRA V/STOL System Research Aircraft

V/STOL Vertical/Short Takeoff and Landing

WAAS Wide Area Augmentation System

WCL Water Conservation Laboratory (USDA)

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

wind shear Variation of wind speed and wind direction with respect to a horizontal or vertical plane; powerful but invisible downdrafts called microbursts focus intense amounts of vertical energy in a narrow funnel that can force an aircraft to the ground nose first if the aircraft is caught underneath

WSF Wake Shield Facility

WTO World Trade Organization

x-rays Radiations of very short wavelengths, beyond the ultraviolet in the spectrum

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