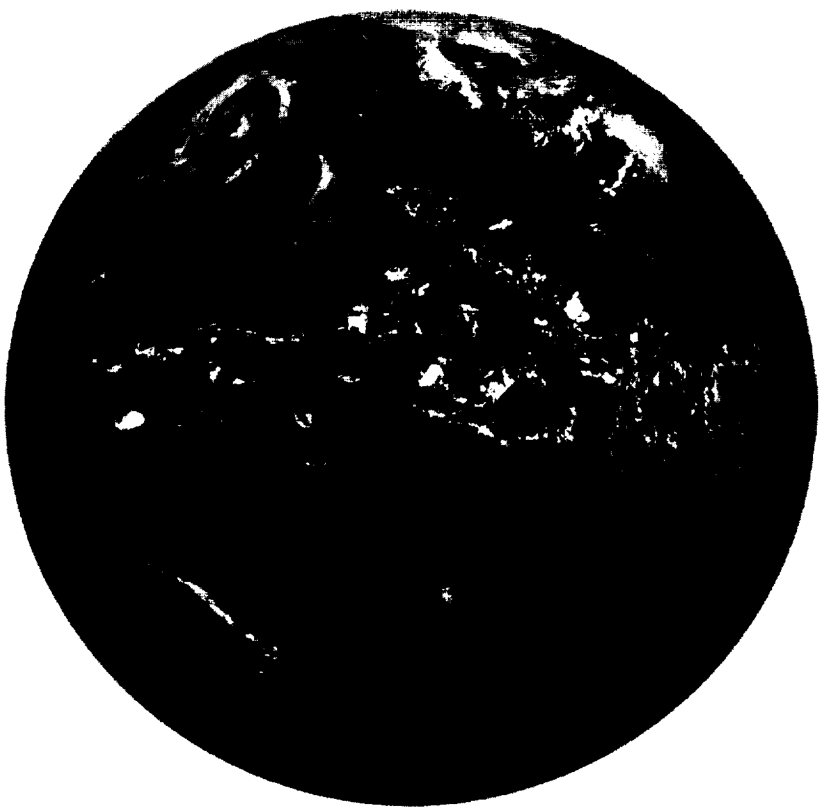
Aeronautics and Space Report of the President



Fiscal Year 1997 Activities

National Aeronautics
and Space Administration

Washington, DC 20546

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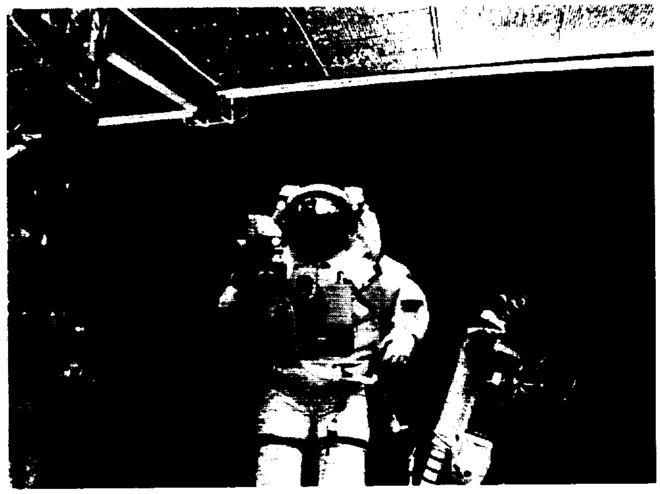
The National Aeronautics and Space Act of 1958 directed the annual Aeronautics and Space Report to include a "comprehensive description of the programmed activities and the accomplishments of all agencies of the United States in the field of aeronautics and space activities during the preceding calendar 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, 1996, through September 30, 1997.



STS-82 Onboard View—Astronaut Mark C. Lee, on the end of the Remote Manipulator System (RMS) arm, photographs a bit of patchwork on the worn insulation material of the Hubble Space Telescope (HST).

National Aeronautics and Space Administration

NASA

During FY 1997, NASA's Space Shuttle program met or exceeded its goals of safety, on-time performance, and cost reduction. NASA successfully launched eight Space Shuttle missions, including three flights that docked with the Russian space station *Mir*. The first mission of the year, STS-80, carried a crew of five, including veteran astronaut Dr. Story Musgrave, who accomplished two noteworthy milestones: tying John Young's record of six space flights for any astronaut or cosmonaut, and at age 61, becoming the oldest person to fly in space. On February 13, 1997, the Shuttle caught up with and retrieved the Hubble Space Telescope (HST) for its second scheduled servicing mission. On six other Shuttle flights, astronauts successfully deployed various space science and microgravity science experiments.

During FY 1997, Shuttle personnel initiated technology upgrade studies on: more powerful and durable fuel cells, more robust thermal protection material; nontoxic fuels for orbital maneuvering and reaction control systems; electric or nontoxically fueled auxiliary power units; more efficient and higher capacity water cooling units; and more efficient processes and techniques for revitalizing the vehicle cabin atmosphere. These studies were all designed with the goals of improved safety and cost efficiency. Shuttle managers also made significant progress in the certification of the new Super Light Weight Tank during FY 1997.

Phase 1 of the International Space Station (ISS) program, the joint U.S. and Russian effort to expand cooperation in human space flight, continued with three successful Shuttle-*Mir* docked missions and two long-duration stays on *Mir* by U.S. astronauts. At the end of FY 1997, technicians had built more than 220,000 pounds of flight hardware, and the ISS program had passed the 60-percent completion milestone. Technicians also transferred major flight elements such as Node 1 and the first two pressurized mating adapters to the Kennedy Space Center for final test and integration in preparation for launch.

Regarding the international agreements governing ISS participation, the 15 participating nations reached ad referendum agreement on the Space Station Intergovernmental Agreement in December 1996, which provides the legal framework for international cooperation. Negotiators also finalized the four bilateral Memoranda of Agreement between NASA and each of the space agencies of Russia, Europe, Japan, and Canada. In addition, NASA personnel negotiated implementing arrangements with Europe and Japan to allow their space agencies to offset the cost of the launch of their ISS elements on the Shuttle through the provision of hardware and other services to NASA. Finally, NASA conducted negotiations with the Brazilian Space Agency (AEB) for the provision of flight hardware by AEB in return for access to ISS utilization.

There were 23 successful U.S. Expendable Launch Vehicle (ELV) launches in FY 1997. Of those, 4 were NASA-managed missions, 2 were NASA-funded/FAA-licensed missions, 5 were DoD-managed missions, and 12 were FAA-licensed commercial launches. There were two launch vehicle failures—a NASA-managed Pegasus mission and a U.S. Air Force-managed Delta mission. As a result of the Pegasus failure, NASA and the Orbital Sciences Corporation completed a detailed assessment of the Pegasus launch system and began seeking areas of mutual cooperation for improving the systems reliability for both Government and commercial use.

In the area of space communications, NASA networks provided support for numerous NASA flight missions. NASA's Mission Control and Data Systems team provided operation of 15 onorbit science missions, including launch and mission support for the Advanced Composition Explorer and the HST servicing mission. In FY 1997, NASA released

STS-84 Onboard View—Crew members from Mir-23 and STS-84 assemble for a group portrait onboard the Spacehab Double Module, as they tie a record (10) for number of persons aboard a single orbiting spacecraft at one time. They are (from left front) Jerry M. Linenger, Vasili V. Tsibliyev, Charles J. Precourt, Aleksandr I. Lazutkin, and C. Michael Foale. In the back row (from left) are Edward T. Lu, Eileen M. Collins, Jean-François Clervoy, Elena V. Kondakova, and Carlos I. Noriega.

The Sojourner rover and undeployed ramps onboard the Mars Pathfinder spacecraft can be seen in this image taken by the Imager for Mars Pathfinder on July 4, 1997.

a Request for Proposal for the consolidated space operations contract to outsource NASA's space operations under a single contract. NASA awarded Phase 1 contracts to develop competing architectures to two industry teams. NASA continued to work with DoD and other agencies to study advanced future communications systems. NASA personnel also made significant improvements to NASA's mission control and data systems as well as ground networks, which contributed to several successful launches as well as significantly reduced operations staff for several orbiting missions.

On July 4, 1997, NASA successfully landed the Mars Pathfinder spacecraft and its Sojourner rover on Mars, garnering worldwide interest, as attested to by the almost 1 billion "hits" at the Pathfinder site on the World Wide Web. Also related to Mars, the discovery by scientists on the Mars Global Surveyor team that Mars has a planetwide magnetic field added to our growing understanding.

Other space science missions yielded fascinating data as well. The Near Earth Asteroid Rendezvous (NEAR) spacecraft made a flyby of Mathilde, which was the closest encounter with an asteroid. The Advanced Composition Explorer began its journey to understand the stream of accelerated particles that constantly bombard Earth. Galileo data indicated that Jupiter's icy moon, Europa, has a metallic core and layered internal structure similar to Earth's, while the heavily cratered moon, Callisto, is a mixture of metallic rock and ice with no identifiable central core. Scientists using the Solar and Heliospheric Observatory spacecraft discovered jet streams of hot, electrically charged gas flowing beneath the surface of the Sun, which may help explain the famous sunspot cycle that can affect Earth with power and communications disruptions. After the second servicing mission of HST, the Hubble provided scientists with dramatic views of a group of baby Sun-like stars surrounding their "mother star," detected a titanic shock wave smashing into unseen gas around a supernova, and found a disk at the heart of a galactic collision.

Several significant Mission to Planet Earth (MTPE) science accomplishments also took place during FY 1997. In land-use/land-cover change, MTPE personnel produced the first global land-cover maps from satellite data. In seasonal-to-interannual climate prediction, MTPE personnel made breakthroughs in observing and understanding the processes that control the initiation of El Niño. In the natural hazards area, MTPE scientists learned to use Synthetic Aperture Radar (SAR) data to distinguish human-induced changes in surface topography, such as subsidence caused by aquifer depletion, from natural tectonic deformation. In long-term climate, MTPE researchers detected a lengthening of the growing season by a week over a 10-year period in some northern latitude regions. MTPE personnel continued to monitor vigilantly atmospheric ozone.

In flight and ground systems, MTPE technicians completed instrument integration for the Tropical Rainfall Measuring Mission and delivered the satellite to Japan prior to launch on November 27, 1997. MTPE managers selected the first two Earth System Science Pathfinder missions to infuse new science elements into MTPE: the Vegetation Canopy Lidar for launch in 2000 and the Gravity Recovery And Climate Experiment (GRACE) in 2001. MTPE also flew several successful experiments, including the Shuttle Laser Altimeter and the German CRISTA-SPAS suite of experiments, on STS-85 in August 1997.

In programmatic terms, MTPE's greatest accomplishment during FY 1997 was the first MTPE Biennial Review, which helped define a new paradigm for missions following the Earth Observing System (EOS) first series with reduced costs and development times. Another major accomplishment was the integration of the Stennis Space Center's Commercial Remote Sensing Program into MTPE.

In FY 1997, the Office of Life and Microgravity Sciences and Applications (OLMSA) conducted research on the Space Shuttle, *Mir*, and ground-based and suborbital facilities. Through three *Mir* missions and the stays of astronauts John Blaha, Jerry Linenger, and Michael Foale, OLMSA continued preparation for living and working on the ISS. OLMSA's Advanced Human Support Technology program conducted several closed-chamber life support tests at NASA's Johnson Space Center. Phase III tests initiated in FY 1997 represented the American record for longest duration closed-chamber tests with human beings. The Microgravity Science Laboratory mission (STS-94 in July 1997) supported several research disciplines, including biotechnology, fluid physics, and materials science, such as combustion research in laminar soot processes. The combustion flight hardware performed flawlessly and gave scientists important new data toward developing methods of controlling pollutant soot emissions. In the field of commercial research, protein crystal growth on STS-86 yielded high-quality crystals; research in agriculture, forest products, and plant-based pharmaceuticals was conducted on STS-94; a commercial research bioprocessing apparatus was tested on *Mir*; and technicians prepared a commercial research plant unit for a *Mir* mission in FY 1998. These last two efforts are precursors to commercial research hardware development for the ISS.

Programmatically, OLMSA realigned its activities into five research programs and three operational functions to reflect streamlined operations at Headquarters and a shift of responsibilities to designated NASA Lead Centers. OLMSA managers also helped form several new research centers: the National Space Biomedical Research Institute, three NASA Centers of Research and Training, and a Commercial Research Center in Informatics at Yale University School of Medicine.

NASA's Aeronautics and Space Transportation Technology Enterprise established three pillars for success: Global Civil Aviation, Revolutionary Technology Leaps, and Access to Space. Within these three pillars, managers defined 10 goals to improve safety, reduce pollution, increase efficiency, and promote new technologies.

During FY 1997, the aeronautics program achieved several major technical milestones. In the High Speed Research program, personnel successfully fabricated advanced bonding panels and, on the propulsion side, selected and completed testing on an advanced inlet concept. In the Advanced Subsonic Technology program, NASA researchers developed the Taxi Navigation and Situational Awareness tool, improving aircraft taxi time and safety in low visibility and night time. In the research and technology base, NASA personnel successfully flew a solar-powered, remotely piloted experimental aircraft to a record 71,300-foot altitude.

During FY 1997, the space transportation technology program achieved several major technical milestones. In the X-33 flight demonstrator effort, researchers completed the hotfire ground test phase of the Linear Aerospace SR-71 Experiment and completed the first piece of X-33 flight hardware, the liquid oxygen tank. The X-34 flight demonstrator program completed wind tunnel testing of a scale model of the vehicle for low-speed flight characteristics. The Bantam Low Cost Booster Technologies program successfully demonstrated a new low-cost engine thrust chamber assembly at flight pressure.

NASA continued to emphasize safety as its number one priority. NASA's Office of Safety and Mission Assurance continued to provide safety oversight and risk analysis for Space Shuttle launches, spacecraft launches, the Shuttle-*Mir* program, and the phase-in of the Shuttle flight operations contract. NASA's ISS Independent Assessment Activity investigated technical and managerial issues and provided practical recommendations to the ISS program to improve safety and performance. NASA instituted a new top-level management policy, providing a functional overview of all safety and mission success policy expectations. NASA also developed assurance guidelines for common spacecraft devices and ELV's and streamlined mission assurance guidelines specifically for the New Millennium program. Finally, NASA made progress in its efforts to implement ISO 9001 as its baseline quality management standard, continuing training and establishing an Agencywide contract for ISO 9001 third-party certification.

NASA's programs continued their trend toward increasing international participation with spacefaring nations around the world. During the past year, NASA signed new agreements with Argentina, Brazil, Canada, France, Germany, Japan, and Russia. Agreements concluded during this period included arrangements for the flight of NASA instruments on foreign spacecraft, the flight of foreign instruments on NASA missions, provisions for a new airborne observatory, and operations support agreements for such activities as overseas Shuttle emergency landing sites and spacecraft tracking, aeronautics cooperation, and data exchange.

NASA supported United Nations activities, including the annual meeting of the Committee on the Peaceful Uses of Outer Space and its subcommittees, the Third Conference of the Americas, and the U.N. Second Regional Conference on Space Technology and Development in Africa. Finally, NASA cosponsored a U.S.-Argentina Joint Conference on Space, Science, and Technology for Society in September 1997 to review past and ongoing cooperation as well as identify opportunities for future cooperation.

Internationally, NASA and NOAA officials signed a Memorandum of Agreement permitting the use of NASA's Russia-to-U.S.-communications circuits in support of the U.S.-Russia Commission on Economics and Technological Cooperation, known more widely as the Gore-Chernomyrdin Commission. NASA representatives also held meetings with colleagues from Japan, the European Space Agency (ESA), and Brazil to foster joint development and use of communications networks.

Department of Defense
DoD

During the past four decades, U.S. national security space systems (that is, the constellations of communications, surveillance, reconnaissance, navigation, and weather satellites) have played an increasingly important role in support of the DoD's overall warfighting capability. During FY 1997, DoD's evolving space capabilities continued to support our national security objectives. In terms of direct support to military operations, DoD's space systems played a crucial role as a force multiplier everywhere U.S. forces were employed, particularly in Bosnia.

During FY 1997, the Military Satellite Communications (MilSatCom) architecture was completed. The MilSatCom architecture was designed to provide medium-data-rate-protected EHF communications, an overall capacity increase, channel-use improvements, and the introduction of a Global Broadcast Service.

In the area of surveillance and warning, DoD continued to develop the Space-Based Infrared System. This is a multimission, multi-orbit infrared detection system to support missile warning and missile defense applications.

DoD emphasized work on navigation warfare to protect location information for friendly forces while preventing its use by an adversary. The first Block IIR satellite launch occurred in FY 1997. In addition, because GPS is an important national resource for both civil and military users, DoD and DoT signed an agreement to identify and plan for a second civil GPS signal.

In the meteorological area, DoD continued to cooperate with its domestic and international partners. In particular, DoD reached agreement with NASA and EUMETSAT on the use of American and European weather satellites to provide high-quality, global weather data to both military and civil users.

DoD initiated an Evolved Expendable Launch Vehicle program and offered two Engineering and Manufacturing Development contracts to the major launch companies. DoD, DoT, and NASA signed an memorandum of agreement that provides for increased access of civil and commercial launch system operators to Federal launch facilities and encourages investment by these non-Federal sectors in launch systems, infrastructure, and facilities. These and other initiatives were designed to strengthen the U.S. industrial base and foster its participation in the expanding global launch market.

In terms of fostering commercial space capabilities, DoD increased its planning to leverage the growing number of commercial space systems for national security purposes. This included the use of commercial launch service and vehicles, as well as communications spacecraft. DoD continued to emphasize dual-use technologies, commercial off-the-shelf products, and flexible manufacturing processes; it is deemphasizing military unique specifications and standards.

The National Reconnaissance Office (NRO) continued to contribute substantially to the expanding flow of vital information to the warfighter, its national customers, and to a growing set of "nontraditional" users, such as civil, environmental, and diplomatic customers. In July 1997, the NRO established a National User Exchange Group to improve national customer understanding of and influence on overhead reconnaissance operations, ongoing acquisitions, and long-term development efforts. In partnership with the newly established National Imagery and Mapping Agency, the Defense Intelligence Agency, and the National Security Agency, the NRO activated a 24-hour situational awareness watch center in October 1996. This center began providing near-real-time status information on NRO satellites to both national and military customers.

View of the soft ground arrestor system being installed at New York's John F. Kennedy International Airport.

Federal Aviation Administration

FAA

The FAA continued a dynamic research and development program in support of its mission to ensure the safe and efficient use of the Nation's airspace, to foster civil aeronautics and air commerce in the United States and abroad, and to support the requirement of national defense. During FY 1997, the agency made great strides in developing an architecture to guide the modernization of the National Airspace System (NAS). The FAA released a draft architecture in October 1996, which will serve as a comprehensive plan to modernize the NAS infrastructure in a way that benefits NAS users and service providers.

A partnership of the FAA, NASA, DoD, and the aviation industry made substantial progress in moving the NAS toward free flight, a concept that could ultimately allow pilots to choose their own routes, speeds, and altitudes during flight. This free flight concept could improve safety, save time and fuel, and be a more efficient use of airspace and our natural environment. In April 1997, the FAA released the Air Traffic Services Concept of Operations, reflecting the user-desired capabilities supporting free flight. In addition, this Government/industry partnership began intensive planning of Flight 2000, a validation and demonstration of these concepts and technologies in the Hawaii and Alaska airspace slated to begin in 2000. In July 1997, the FAA released the Flight 2000 Initial Program Plan, outlining increased safety, services, low-cost avionics, streamlined certification processes, and risk reduction.

During the fiscal year, the FAA continued research activities in numerous areas of aviation safety, including structural integrity, nondestructive inspection, flight loads, and crashworthiness. In the airports technology area, the FAA teamed with the Boeing Company to begin construction of the National Airport Pavement Test Facility, located at the FAA's William J. Hughes Technical Center in Atlantic City, New Jersey. In response to a number of aircraft accidents attributed to the presence of ice on critical aircraft surfaces, the FAA joined with the U.S. Air Force to develop an aircraft-mounted system to monitor the condition of the wing. FAA engineers made significant progress in improving the performance of aircraft interior materials during fire, developing new standards for lavatory fire extinguishers, developing new materials with increased fire resistance, and providing fire test support to the National Transportation Safety Board in the investigation of the May 1996 ValuJet accident. The FAA also cosponsored a joint DOD-FAA-NASA conference on continued airworthiness of aircraft structures, held in July 1997. In September 1997, the FAA announced the selection of a team of universities to serve as the new FAA air transportation center of excellence for airworthiness assurance.

The FAA continued to acquire new automation systems for the NAS. During 1997, the agency made hardware infrastructure improvements, installing state-of-the-art computers at five en route centers to replace failing display channels well ahead of schedule. In addition, the agency deployed the final 6 voice switching and control systems, bringing to 21 the number of systems in operation at en route centers. The FAA also completed and certified the first software improvements to these state-of-the-art digital switching systems. The agency deployed to all 21 en route centers a system that provides emergency access to radios in the event of failure of the primary system, reducing the probability of total communications loss to aircraft operating under air traffic control.

In FY 1997, the micro en route automated radar terminal system became fully operational at the Anchorage, Honolulu, and Guam offshore facilities. The agency also completed a test to reduce the vertical separation standards from 2,000 to 1,000 feet over North Atlantic airspace while maintaining strong safety standards and then implemented the new standards at the New York oceanic center. Ground-to-ground data link communications via the air traffic services interfacility communications system also became operational at the New York facility during the year, enabling a more efficient transfer of aircraft navigation information and providing more timely position and performance data to controllers.

In 1996, the FAA's Aviation Security Research and Development Division and the United Kingdon's Civil Aviation Authority collaborated to study blast effects on commercial wide-body aircraft and potential mitigation methods by exploding a pressurized Boeing 747-100 at Bruntingthorpe Airfield, Leicestershire, England.

During the year, a more effective aviation forecast system, providing a national gridded data base of weather information, began operating at the Aviation Weather Center in Kansas City, Missouri. Also, a deicing decisionmaking system began formal evaluation at New York's LaGuardia and Chicago's O'Hare Airports. In addition, the agency commissioned 79 more automated surface observing systems, providing automated weather observing and reporting capabilities at 188 airports. The FAA also completed the first phase of development and deployment of a new state-of-the-art automated weather and radar processor system that collects, processes, and disseminates hazardous weather warnings and advisory information to air traffic controllers, traffic managers, meteorologists, and other users.

On October 30, 1996, the Secretary of Transportation announced the creation of an FAA security equipment integrated product team to acquire advanced security equipment. Based on the recommendations of the White House Commission on Aviation Safety and Security, this team purchased trace detection equipment to be used to screen carryon and checked bags. The FAA began deploying 57 CTX-5000's, the only FAA-certified explosives-detection system, to all major airports. The FAA awarded grants to the CTX-5000 manufacturer, InVision, and to L-3 Communications to develop second-generation computed tomography systems.

The FAA and its research partners continued to test hardened containers for use in aircraft cargo holds. On May 17, 1997, the FAA, in conjunction with the Civil Aviation Authority in the United Kingdom, conducted a blast test on a Boeing 747, detonating four simultaneous explosions in the four quarters of the 747 cargo bay under pressurized conditions. The test met all technical objectives and indicated no appreciable damage to the airframe. In addition, the FAA, in conjunction with the New Mexico Institute of Mining and Technology, acquired a fuselage facsimile of hardened armor plating that can be configured to the exact parameters of an aircraft cargo compartment for repeated tests. The FAA began using this unit to validate vulnerability estimates, compare the effects of various types of explosives, and test and validate new aircraft-hardening concepts including containers.

During FY 1997, FAA researchers used human-factors-workload-baseline studies to examine the implications of airway facilities consolidation. Human factors specialists also completed a study to evaluate the performance impact of digital ground-to-air communications technology known as "vocoders," establishing clear controller preferences between alternative "vocoder" instruments and showing that air traffic controllers could use "vocoders" effectively. Researchers supported the deployment and evaluation of the Systematic Air Traffic Operations Research Initiative tool to four en route centers to help assess controller operations and deployed the first user-tailored version of the Automated Performance Measurement System to an air carrier for operational tests. This system provides the ability to analyze routine operations for safety trends and tendencies, providing the airlines and the FAA an accurate insight into the details of daily air-carrier line operations.

In general aviation, human factors researchers concluded several studies of aeronautical decisionmaking and produced a training videotape, instructing general aviation pilots on ways to set their personal minimums and create a personal checklist to improve safety. Using the Civil Aeromedical Institute's simulators, human factors specialists conducted research on Global Positioning System (GPS) navigation display formatting, the effects of grouping air traffic control message units in air/ground communications, and the baselining of pilot performance to assess the effects of free flight options.

The FAA and the National Institute for Occupational Safety and Health began a 5-year study to address inflight disease transmission issues. Researchers also completed an initial evaluation of inflight medical events in the domestic air-carrier population and developed new DNA probes that permit the identification of microbes in postaccident human samples. FAA studies indicate that current projections for pilots dying in aviation accidents indicate a positive blood alcohol level (greater than or equal to 0.04 percent) in about 9 percent of the accident cases, an indication of over-the-counter drugs in 21 percent of the cases, and prescription drugs in 16 percent of the cases. Researchers also discovered controlled dangerous substances (e.g., schedule I: LSD and heroin; and schedule II: morphine, codeine, and cocaine in 7 percent of the cases; and schedule III: paregoric and schedule IV: phenobarbital and valium in 4 percent of the cases).

During the fiscal year, FAA's Associate Administrator for Commercial Space Transportation issued five launch licenses, including one to Lockheed Martin for the first commercial launch to the Moon, as well as one license to operate a launch site (Spaceport Florida). The FAA issued 10 license amendments primarily addressing financial responsibility requirements. In addition to other routine inspections, the agency monitored 14 licensed commercial launches, including the first licensed launch from a foreign country when Orbital Sciences Corporation conducted a launch from Spain using its Pegasus launch vehicle. The agency also entered into a Memorandum of Agreement with DoD and NASA, to define the roles and responsibilities of each agency with respect to spaceports and commercial users of Federal services and facilities. The FAA also compiled and published projections on the low-Earth orbit commercial market.

On March 19, 1997, the FAA published in the *Federal Register* a Notice of Proposed Rulemaking on the licensing of commercial launches conducted from Federal launch sites and has been working on a final draft of this rule based on public comments. During the fiscal year, the agency made significant progress in developing the technical safety requirements to be used in the licensing regulations on launches from non-Federal ranges. In addition, it developed and validated the technical requirements for assessing the suitability of launch sites. The agency also began developing standards and criteria for the operation of reusable launch vehicles under FAA's licensing process.

GOES-10 launch.

Department of Commerce

DoC

The National Oceanic and Atmospheric Administration's (NOAA) new generation of Geostationary Operational Environmental Satellite (GOES) spacecraft continued to provide two-satellite operational environmental monitoring throughout FY 1997. GOES-10 was launched April 25, 1997. NOAA's Polar-orbiting Operational Environmental Satellite (POES) program, which also consists of two primary satellites, NOAA-12 and 14 (with three older spacecraft serving as backup), covered the globe at least twice daily, monitoring weather, forest fires, volcanoes, and other environmental dangers. NOAA moved forward with DoD and NASA on plans to converge into a single system the civilian POES program with the DoD's polar Defense Meteorological Satellite Program (DMSP). Toward this end, NOAA completed a refurbishment of its satellite control center at Suitland, Maryland, which will allow for single-entity control of POES and DMSP operations.

NOAA continued generating satellite remote-imaging data products from its own and DoD satellites, providing innovative access to these data online. Of note were four new GOES products (moisture soundings, high-density winds, derived product imagery, and daily snow cover products) and one POES product (an experimental drought index product). The four GOES products will be operationally implemented for use by the National Weather Service. The Department of Agriculture found the drought index extremely useful in monitoring agricultural production in critical regions of the world. NOAA also continued to promote the President's 1994 policy to foster growth of the commercial remote-sensing industry, by issuing another license (bringing the total to 12) to operate private remote-sensing systems and by approving two other associated foreign agreements and amendments.

In the area of satellite-aided search and rescue, NOAA continued to operate the U.S. Cospas-Sarsat Mission Control Center, which receives alert data from U.S. and Russian satellites and provides the information to the appropriate U.S. or foreign rescue coordination center. In FY 1997, NOAA continued its work with NASA to integrate French and Canadian Sarsat instrumentation on the current series of POES satellites. NOAA also participated in a productive international demonstration and evaluation of the use of geostationary satellites, such as NOAA's GOES satellites, as a potential enhancement to the international Cospas-Sarsat program.

On the international front, NOAA personnel negotiated with the European Union (EU) for the Exploration of Meteorological Satellites (EUMETSAT) for a joint polar satellite system, taking into account, on the U.S. side, the converged civil-military U.S. system. This agreement was expected to be signed in FY 1998. On March 31, 1997, NOAA, NASA, and Japan's National Space Development Agency (NASDA) signed a Memorandum of Understanding on Japan's Advanced Earth Observing Satellite-II (ADEOS-II) program. NOAA, together with NASA, worked to further develop the Integrated Global Observing Strategy (IGOS) with international space and Earth observing agencies, hosting the first meeting of the IGOS Strategic Implementation Team in February 1997, at which senior officials commissioned the development of six prototype projects to test the IGOS concept.

DoC's Office of Air and Space Commercialization (OASC) ensured that U.S. commercial space interests were represented in the formulation of space-related Government policies and agreements. OASC personnel represented DoC in discussions with the governments of Japan, Russia, and the European Community regarding the harmonization and integration of the GPS for worldwide civil and scientific applications. DoC focused on the potential international GPS market and advocated the removal of potential nontariff trade barriers to maintain continuous growth in the GPS market. OASC participated, as senior representatives of DoC, in the annual consultations led by the U.S. Trade Representative under the bilateral commercial space launch trade agreements with the governments of China, Russia, and Ukraine.

The International Trade Administration (ITA)'s Office of Aerospace (OA) also contributed to the annual consultations of the commercial space launch agreements that the United States has signed with Russia, China and Ukraine. The OA participated in discussions with the EU under a 1992 agreement on Trade in Large Civil Aircraft and with a World Trade Organization Subgroup, the GATT Aircraft Committee. The OA also provided support for U.S.-Japanese, U.S.-Russian, and U.S.-European discussions on the worldwide use of GPS. To promote the export of U.S. aerospace products, OA sponsored the partially privatized U.S. National Pavilion at the Paris Air Show. OA also sponsored six aerospace product literature centers at major international aerospace exhibitions and air shows. OA also worked with ITA's Advocacy Center on numerous international aerospace competitions, including helicopters, commercial transport aircraft, and space launch vehicles. OA participated in the aerospace-related subgroups of the U.S.-Russia Business Development Committee and U.S.-China Joint Commission on Commerce and Trade. In addition, OA worked with the Trade Development Agency to conduct reverse trade missions to the United States from Spain and Argentina.

ITA's Office of Telecommunications (OT) participated in negotiations with the government of Argentina on satellite services. OT also provided sector expertise to ITA's Advocacy Center for several major satellite companies. OT commissioned a study on commercial applications of GPS and the international competitiveness of the U.S. industry. OT provided business counseling services to numerous satellite companies seeking to do business abroad.

As the lead advisory agency for Federal 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 the International Telecommunications Satellite Organization (INTELSAT) and the International Mobile Satellite Organization (INMARSAT). While the Federal Communications Commission continued to regulate the electromagnetic spectrum for commercial users, NTIA managed the Federal Government's use of the spectrum and helped clear unexpected regulatory hurdles. NTIA engineers 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.

The National Institute of Standards and Technology performed a wide variety of research in support of aeronautics and space activities during FY 1997. The institute received funding from NASA Headquarters and seven NASA Centers for 43 projects, totaling $4.4 million in research and development activities.

Department of Energy
DoE

In FY 1997, DoE completed the fabrication and testing of three general purpose heat source radioisotope thermoelectric generators (GPHS-RTG) and 157 lightweight radioisotope heater units (LWRHU) for NASA's Cassini mission to Saturn. DoE provided launch support for NASA's Mars Pathfinder mission, which contained three DoE LWRHU's. DoE continued studies of advanced converter technologies to provide high-efficiency, lightweight power systems for future NASA missions.

When Mars Pathfinder crash-landed on Mars in July 1997, the impact was cushioned by air bags designed at DoE's Sandia National Laboratories. The work was part of a joint effort between Sandia and the Jet Propulsion Laboratory to improve the feasibility of air bags for planetary probes. Sandia's nuclear weapon parachute technology served as the basis for proposing air bag configurations that had to be light enough to fit aboard Pathfinder, yet strong enough to withstand high vertical velocities, impacts, and horizontal wind velocities expected at the Martian surface.

Department of the Interior
DoI

In terrestrial studies and applications, DoI increased the deployment and use of GPS receivers because of the growing demand for real-time positioning in wildland areas that are out of reach of traditional differential methods. The Bureau of Indian Affairs (BIA) increased its use of GPS technology to satisfy field-mapping requirements and expanded GPS training programs for bureau and tribal personnel. The use of GPS technology also proliferated throughout the National Park Service (NPS) for natural resource, cultural resource, and park maintenance applications. The Minerals Management Service (MMS) continued to use GPS to position offshore oil and gas platforms and wells. Office of Surface Mining inspectors used GPS technology to determine the premining status and condition of surface resources, to prepare reclamation plans and contracts, to determine reclaimed acreage, to confirm that lands have been adequately restored upon reclamation, and to locate features that require regular inspection.

The BIA extensively used Landsat and Satellite Pour l'Observation de la Terre (SPOT) satellite imagery, as well as aerial photography from the National Aerial Photography Program (NAPP) and commercial sources, to generate image maps, inventory natural resources, conduct environmental assessments, and support other Geographic Information System (GIS) analyses. The MMS used remotely sensed data from several sources as part of environmental studies. The NPS used Landsat and SPOT data to map and monitor land cover, vegetation, and other specific features in many parks from Alaska to Florida.

The Bureau of Reclamation used high-spatial-resolution panchromatic imagery from the Indian Remote Sensing satellite (IRS-1C) and multispectral Landsat Thematic Mapper (TM) imagery for agricultural monitoring projects in the Colorado, Columbia, and Yellowstone River basins. The bureau also used Landsat TM imagery to map wildland vegetation in several Western States.

The Bureau of Land Management routinely used remote-sensing technology in all regions. An important application was the "routes of travel" inventory mandated by Presidential Executive Order for the 1.5-million-acre West Mojave Planning Unit in southern California. Data from SPOT satellites, NAPP aerial photography, digital orthophotography, digital cartographic data, GPS, and National Technical Means were integrated to build a comprehensive route inventory data base.

The U.S. Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center continued to prepare for the upcoming Earth Observing System (EOS) AM-1 and Landsat 7 missions by installing the antenna system for direct reception of Landsat 7 data and the computer systems that will process, archive, and distribute EOS and Landsat 7 data and products. The center has also collected, processed, and archived more than 160,000 daily Advanced Very High Resolution Radiometer (AVHRR) observations since 1992 for the Global Land 1-km AVHRR Pathfinder Project, in cooperation with NASA, NOAA, and several international partners. The EROS Data Center created two major global land data sets and made them available over the Internet—the first global digital topography and land cover data sets covering Earth's entire land surface at 1-km resolution. Global change researchers now have a significantly better representation of Earth's land surface and land cover that will improve the results of Global Circulation Models and other computer-based models of Earth processes.

The USGS continued to use Landsat TM/Multispectral Scanner (MSS), SPOT, AVHRR, and radar data for a wide variety of mapping and research applications, including Statewide vegetation mapping through partnerships in the Gap Analysis Program; habitat and land-use mapping; fire fuels mapping; sea-surface temperature measurement; snow hydrology; fisheries monitoring; contaminants analysis; wetlands restoration; and the documention of both short- and long-term trends or changes in wildlife habitats. The USGS analyzed imaging spectroscopy data over the Leadville, Colorado, superfund site and mapped key minerals that generate acid mine drainage. By using this new technology, the Environmental Protection Agency (EPA) accelerated the cleanup by 2.5 years and saved over $2 million in site-assessment costs.

The Multi-Resolution Land Characterization project (a joint activity of USGS, EPA, NASA, NOAA, and other agencies) released high-resolution land-cover data sets derived from Landsat data for Delaware, Maryland, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Virginia, and West Virginia.

The USGS participated actively with NASA in planning for the Shuttle Radar Topography Mission. USGS investigators also worked with NASA personnel at the Jet Propulsion Laboratory (JPL) on the New Millennium program, which will demonstrate advanced technologies for use in the next generation of spacecraft missions, such as LightSAR.

In the area of space science, the USGS played a major role in the success of NASA's Mars Pathfinder mission, including support in site selection and certification and in postlanding publicity. USGS scientists provided basemaps and images for detailed scientific analyses of the landing site, and they studied the light and color properties of Mars and the planet's geologic and geomorphic surface processes. The USGS was also involved in the Mars Orbital Camera and the Thermal Emission Spectrometer teams of NASA's Mars Global Surveyor mission. USGS investigators also worked with JPL colleagues to support the new astrobiology initiative that will precisely define this evolving discipline and to develop strategies to support the Mars surface sample return missions of the next decade.

Department of Agriculture

USDA

The Agricultural Research Service (ARS) Remote Sensing and Modeling Laboratory evaluated procedures to map crop conditions and worked to develop a sensor to measure crop residue cover. The ARS Hydrology Laboratory conducted the Southern Great Plains Hydrology Experiment to design and develop a system to measure global surface soil moisture and its influence on the atmosphere. It also conducted an experiment at the Jornada Experimental Range and the Sevilleta National Wildlife Refuge in New Mexico to determine the effect of scale on landscape measurements of heat and energy fluxes. The ARS Conservation Laboratory in Phoenix, Arizona, used remote sensing to derive information from the spectral properties of vegetation canopies. The Remote Sensing Research Unit (RSRU) at Weslaco, Texas, continued work on a Cooperative Research and Development Agreement to design and calibrate a digital video imaging system to assess natural resources. Working with EPA, RSRU continued to evaluate a digital imaging video system to aid farmers.

The Foreign Agricultural Service's (FAS) satellite remote-sensing program remained a critical element in USDA's analysis of global agricultural production and crop conditions by providing timely, accurate, and unbiased estimates of global area, yield, and production. Satellite-derived early warning of unusual crop conditions and production enabled more rapid and precise determinations of global supply conditions. FAS used NOAA, AVHRR, Landsat, IRS, and SPOT imagery, crop models, weather data, attaché reports, field travel, and ancillary data to forecast foreign grain, oilseed, and cotton production. FAS remote sensing supported Department of State assessments of food needs in the former Soviet Union, Bosnia-Herzegovina, and North Korea. Also, FAS prepared detailed analyses of the U.S. northern Great Plains snowpack/flooding, El Niño, and flooding in Eastern Europe.

The Farm Service Agency (FSA), which funded the FAS analysis of imagery, received timely reports on U.S. crop conditions from FAS. These imagery-based reports, combined with weather data, crop model results, and GIS products, made possible the development of accurate and timely projections and comprehensive evaluations of crop disaster situations. FSA continued to be a partner in the National Aerial Photography Program (NAPP) and National Digital Orthophoto Program (NDOP). FSA also fielded geometric, distortion-free photographs created from Russian KVR-1000 imagery of Hawaii.

The Forest Service used a wide range of remotely sensed data to manage the 191 million acres of land in the National Forest System. To improve forest management planning, the Forest Service, with NASA's support, collected high-altitude aerial photography over the two largest national forests in the United

States—the Tongass and Chugach National Forests in Alaska. To improve wildland fire management, the Forest Service also worked with NASA by participating in an interagency workshop on monitoring wildland fires from space.

The National Agricultural Statistics Service (NASS) used remote-sensing data to construct area frames for statistical sampling, to estimate crop area, to create crop-specific land-cover data layers for GIS, and to assess crop conditions. For area frame construction, NASS 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 of cultivation or other variables. NASS personnel implemented new remote-sensing-based area frames and samples for Delaware, Maryland, and New Jersey. The remote-sensing acreage estimation project analyzed Landsat data of the 1996 crop season in Arkansas and then collected 1997 crop season data for Arkansas, North Dakota, and South Dakota. End-of-season TM analysis produced crop acreage estimates for major crops at State and county levels plus a crop-specific categorization usable for digital GIS analysis. In addition to conventional survey data, vegetation condition images based on AVHRR data helped assess crop conditions.

The Natural Resources Conservation Service (NRCS) continued its partnership with Federal and State agencies in sharing costs to develop 1-meter digital orthophotography coverage through the NDOP. At the end of FY 1997, 67 percent of the Nation's digital orthophotography maps were either complete or in progress. NRCS continued to use digital orthophotography coverage as a basemap for all GIS and program mapping activities. NRCS cooperated with DoD on the purchase of GPS precise positioning service receivers and increased its use of GPS in daily field operations.

Federal Communications Commission

FCC

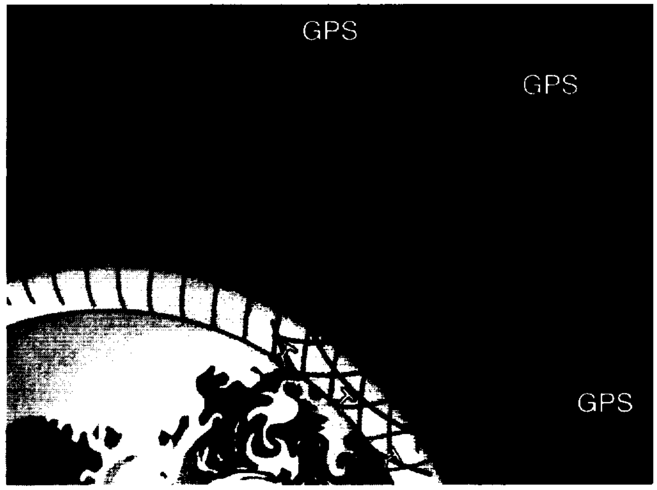
The FCC authorized the construction, launch, and operation of numerous fixed-satellite service satellites in FY 1997. In accordance with FCC authorization, PanAmSat launched PAS-8 in May 1997 and PAS-9 in August 1997. The FCC authorized the American Telephone and Telegraph Company and the General Electric Corporation to deploy two hybrid C/Ku-band satellites in 1998. The FCC also authorized GE Americom to launch GE-3, which was deployed on September 4, 1997. The FCC authorized Comsat to participate in the launch of three INTELSAT-8 series satellites.

In accordance with its FCC license, Iridium launched 34 of the 66 low-Earth orbit satellites that will comprise its full constellation. It is anticipated that this system will be the first in a new generation of nongeostationary satellite systems providing mobile services.

In March 1997, the FCC authorized Teledesic to construct, launch, and operate a constellation of 840 nongeostationary satellites to provide fixed-satellite service in the Ka-band. In May 1997, the FCC adopted an orbital assignment plan for geostationary fixed-satellite service systems proposed in the Ka-band and awarded 13 system licenses.

The FCC awarded the first two licenses for the satellite Digital Audio Radio Service through the auction process. Licenses went to Satellite CD Radio and American Mobile Radio Corporation. This mobile service will operate in the S-band and is expected to provide Nationwide radio programming with compact disk quality. Through the auction process, the FCC awarded licenses to Echostar and MCI to provide digital broadcast satellite service.

The FCC authorized Mobile Communications Holdings, Inc., and Constellation Communications, Inc., to provide mobile satellite service in the L-band. Mobile Communications Holdings was authorized to operate a constellation of 16 nongeostationary satellites, while Constellation was authorized to operate a constellation of 46 satellites.



This schematic diagram of GPS meteorology shows GPS signals passing from GPS satellites, orbiting at heights of ~20,000 km, through the intervening Earth's atmosphere to ground-based receivers and to a low-Earth orbit satellite.

National Science Foundation

NSF

NSF-sponsored research projects continued to contribute new knowledge about the origins, composition, and dynamics of the universe. Astronomers at the University of Oklahoma and the University of Texas recently arrived at a new estimate of the age of the Milky Way galaxy that is independent of both stellar evolutionary or cosmological models. By measuring the abundance of thorium in emissions from an extremely old star, these scientists have estimated the age of the galaxy as 17, plus or minus 4 billion years.

Scientists at the National Radio Astronomy Observatory in New Mexico, at the California Institute of Technology, and in Italy made the first measurements of the size and expansion of the mysterious, intense "fireball" resulting from a particular cosmic gamma-ray burst. The radio observations have revealed a size of the fireball, unobtainable by any other technique, thereby enabling astronomers to learn about inner workings of such objects.

NSF-supported scientists used the Very Large Baseline Array telescope to image a light-year-sized radio jet in a relatively nearby spiral galaxy called NGC 4151, located approximately 43 million light-years from Earth. This galaxy is believed to contain a black hole with a mass that is millions of times greater than the mass of the Sun.

In response to the intriguing but controversial announcement that a team of scientists had discovered evidence of ancient life in a meteorite from Mars discovered in Antarctica in 1984, NSF and NASA developed a cooperative research program to investigate and shed light on this interpretation. NSF, NASA, and the Smithsonian Institution continued to manage Antarctic meteorites cooperatively.

NSF-sponsored studies also contributed to new understandings of the Earth. Researchers at the University of Illinois used a high-power lidar instrument in conjunction with the large, steerable optical telescope at Kirtland Air Force Base in New Mexico to make more sensitive measurements in the middle atmosphere of vertical heat fluxes, cooling rates, and particle movements associated with the dissipation of pressure waves that originated in the lower atmosphere. In the past year, the spectra of wave-induced perturbations in temperature, winds, and density have been measured simultaneously and compared with the predictions of the leading wave-dissipation paradigms. In addition to examining relationships between horizontal winds and pressure waves in new ways, the researchers are analyzing in unprecedented detail the characteristics of distinctive wave perturbations in temperature, winds, and density in the middle atmosphere, which is very sensitive to global change effects.

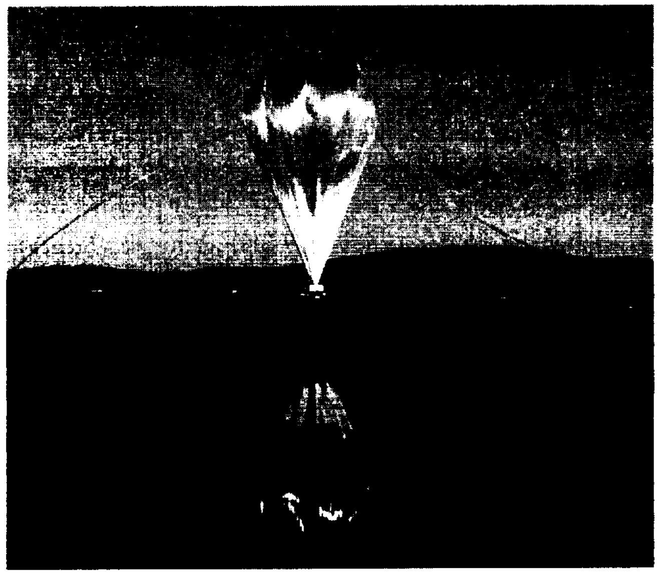
Arctic noctilucent clouds over Sondre Stromfjord, Greenland, have been studied using simultaneous backscatter lidar and ultraviolet spectrograph measurements. The combined measurements provide unique information about the sizes and density of the particles that make up these high-altitude clouds and also about the processes that disperse them.

Images from the first radar survey of Antarctica, using the Canadian Space Agency's Radarsat satellite, provided exciting new images of NSF's South Pole Station and of several segments of the Antarctic coastline. These images show some of the large glaciers that drain the vast ice sheet over Antarctica. In addition, NASA and NSF established a ground station at McMurdo Sound to acquire ozone data from the Total Ozone Mapping Spectrometer Earth Probe.

NSF researchers successfully completed the GPS-Meteorological (GPS-MET) proof-of-concept experiment. GPS-MET used a low-Earth-orbiting satellite that measured the way signals from GPS satellites bent as they passed at oblique angles through various layers of Earth's atmosphere. By analyzing these signals, scientists improved their capabilities for estimating ionospheric electron density, atmospheric density, pressure, temperature, and moisture profiles in the atmosphere to support weather research and prediction, climate research and climate-change detection, and ionospheric physics research.

NSF also continued to upgrade its facilities for space research. Most notably, in June 1997, a 5-year, $27 million upgrade to the world's most sensitive radio/radar telescope at Arecibo Observatory in Puerto Rico was completed with joint support from NSF and NASA.

On April 30, 1997, the SAO's Far Infrared Spectrometer 2 (FIRS-2) balloon-borne measurement system was flown successfully into Earth's stratosphere above the Arctic. FIRS-2 was launched from Ft. Wainright, Alaska (near Fairbanks), at 7:15 a.m., on a gondola supplied by NASA's Jet Propulsion Laboratory (JPL).



Smithsonian Institution

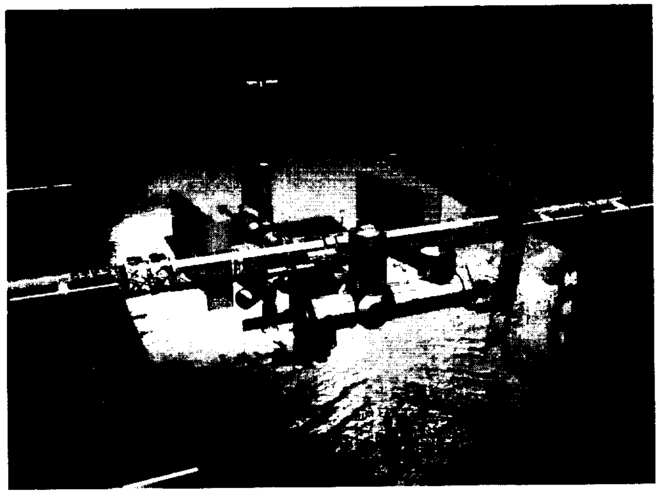
The Smithsonian Institution contributed to the national space program through the research of staff scientists at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts, and at the Center for Planetary Studies based at the National Air and Space Museum in Washington, D.C. Based on observations of x-ray binary stars made with the Japanese-NASA Advanced Satellite for Cosmology and Astrophysics, SAO scientists and their colleagues were able to confirm the existence of a previously theoretical phenomenon known as an "event horizon," the one-way membrane surrounding a black hole, and the place at which all forms of matter and energy, including light, begin to fall into this gravitational trap, never to escape. Two SAO scientists used HST's Fine Object Camera to obtain ultraviolet and optical images of the giant star Mira A and its hot companion, representing both the first ultraviolet images of the two objects, as well as the first separate spectra of the two stars ever obtained. The unique images suggest that material from Mira's extended atmosphere is being drawn onto the smaller companion.

A balloon-borne Far Infrared Spectrometer 2 (FIRS-2), designed and built at SAO, made its 10th successful probe of Earth's stratosphere on April 30, 1997, during a 5-hour flight over Alaska. The FIRS-2 instrument measured high-altitude gases vital to understanding atmospheric photochemistry, especially ozone depletion and the greenhouse effect. This flight was a part of the international validation campaign for the Advanced Earth Observing Satellite, launched by the National Space Development Agency of Japan.

The SAO-designed Ultraviolet Coronagraph Spectrometer on board the ESA-NASA Solar and Heliospheric Observatory measured particle velocity distributions in the inner solar corona. Scientists were surprised at how different these distributions were from their expectations and plan to use these data to help unravel the complicated processes that determine the acceleration of the solar wind.

Using a new quick and efficient method, SAO scientists demonstrated how finding elusive brown dwarf stars could become easier. The astronomers took pictures of Gliese 229, a reported brown dwarf system, with an infrared camera at NASA's Near Infrared Telescope Facility in Hawaii. They first observed the system through a filter that favored methane absorption and then through another filter that excluded it. Comparing the various filtered images helped subtract out objects that are not truly brown dwarfs. This method, in addition to requiring very little telescope time, may reduce the number of false alarms in searches for brown dwarfs.

The International Space Station (ISS) presents the opportunity for several nations to work together toward a singular goal.



Department of State
DoS

Working closely with NASA, DoS completed negotiations with Russia, Europe, Japan, and Canada on a multilateral agreement integrating Russia into the ISS partnership. DoS also consulted with Japan, the European Union, and Russia on issues related to GPS. DoD took the lead on an inter-agency process to prepare for participation by the United States in a major United Nations conference on "Space Benefits for Humanity" in the 21st century, known as "Unispace III," which will be held in Vienna, Austria, in 1999. DoS was instrumental in organizing the first U.S.-Argentina Joint Conference on Space, Science and Technology for Society, which was held in Buenos Aires, Argentina, on September 22–23, 1997. In addition, DoS served as the lead agency for U.S. delegations to meetings of the INTELSAT and INMARSAT member countries and provided relevant policy guidance to Comsat, the U.S. signatory organization. DoS officials also promoted access to overseas markets for commercial satellite companies and worked to resolve complex problems of orbit and spectrum availability.

Arms Control and Disarmament Agency
ACDA

During FY 1997, the Arms Control and Disarmament Agency (ACDA) supported missile nonproliferation efforts and worked to prevent the acquisition of offensive ballistic missile programs by other countries, particularly in South Asia and the Korean Peninsula. ACDA personnel worked on Strategic Arms Reduction Treaty (START) issues related to the use of excess ballistic missiles.

ACDA worked to strengthen and expand the scope of the 29-nation Missile Technology Control Regime (MTCR), which is intended to prevent the proliferation of missiles, space launch vehicles, and other remotely piloted (unmanned) aerial vehicles capable of delivering weapons of mass destruction. ACDA participated in discussions on outreach programs for key transshipment countries and the preparation of an international MTCR handbook to detail the items controlled by the MTCR Equipment and Technology Annex. ACDA participated in negotiations involving the international use of GPS and helped craft technical safeguards agreements governing the control of technology involved in launching U.S. satellites abroad. ACDA also supported the vigorous implementation of U.S. sanctions legislation against entities in North Korea, among others.

ACDA worked on the development of U.S. policy related to the use of U.S. ballistic missiles made excess under the START I and START II treaties. The United States intends to retain such missiles for U.S. Government use or eliminate them. The United States has encouraged other governments with excess ballistic missiles to adopt a similar policy. Additionally, the START I parties, since confirming in the fall of 1995 that all space launch vehicles that use the first stage of an intercontinental ballistic missile (ICBM) or a submarine-launched ballistic missile (SLBM) are accountable as ICBM's or SLBM's of that type under the Treaty, have exchanged policy commitments not to construct silo launchers of ICBM's at space launch facilities located outside of their national territory. This commitment will support nonproliferation efforts.

ACDA continued to be an active member of several interagency committees concerned with missile-related issues. At the policy level, these include various committees chaired by the National Security Council, such as the Interagency Working Group on Nonproliferation and Export Controls and the Interagency Working Group on Arms Control. ACDA participated in the Missile Trade Analysis Group, which reviewed intelligence related to international transfers of missile-related items, and in the Missile Technology Export Control Group, which reviews export license applications subject to missile proliferation controls. ACDA actively supported the efforts of the United Nations Special Commission on Iraq to destroy or remove from Iraq any materials, equipment, and facilities related to missiles with a range greater than 150 kilometers. ACDA also participated in the Weapons and Space Systems Intelligence Committee to ensure that U.S. policy initiatives were based on accurate intelligence assessments.

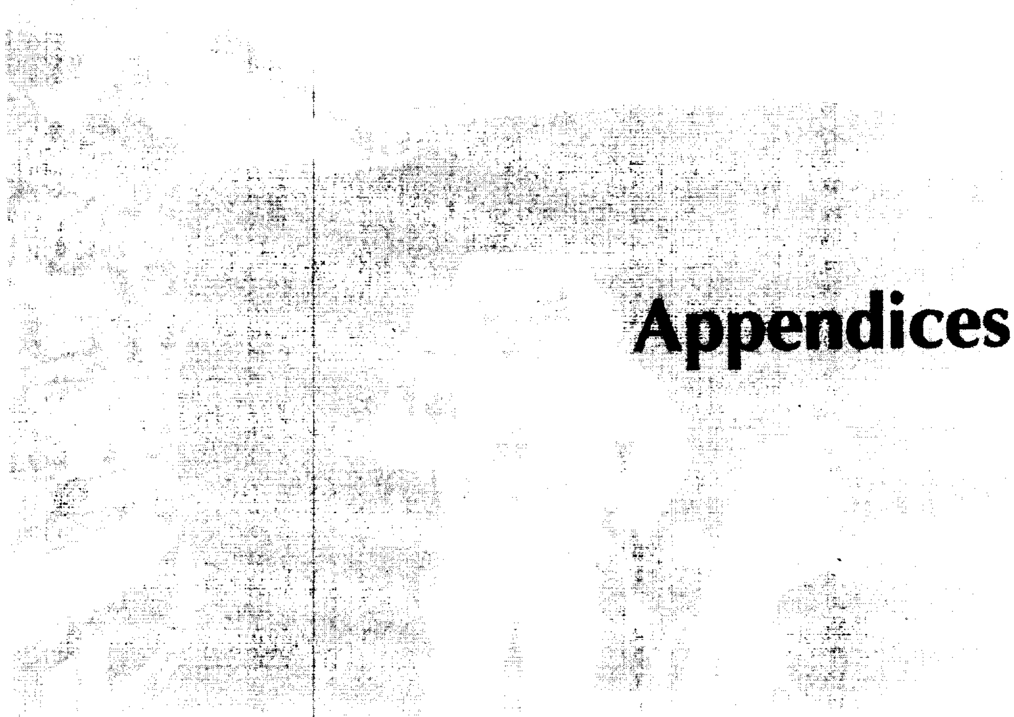
U.S. Information Agency
USIA

As part of its mission to bring significant American achievement to foreign audiences, USIA presented NASA's activities in a variety of formats and languages. It provided regular coverage of NASA-related events in its news services, the print-based Washington File, the Voice of America's (VOA) news broadcasts, and WORLDNET Television's Newsfile. Other feature stories and thematic programs, often presented in local languages, carried accounts of NASA's work and related topics to all regions of the world. For instance, the Ukrainian-language program "Window on America," a joint VOA and WORLDNET project, offered approximately 30 stories on NASA, with special emphasis on the Mars probe and Space Shuttle missions, especially those dealing with the *Mir* space station.

NASA officials and astronauts made themselves available for a number of USIA programs. VOA's "Talk to America," an international call-in show heard around the world, featured several NASA representatives, including Dr. Robert Parker, Director of Space Operations, and Stephen Garber, from the NASA History Office, discussing the space program. Other cooperative programs involved visits by astronauts and NASA scientists to Mali, Slovenia, and Chile.

Two other USIA-sponsored astronaut visits were prominent. One was Winston Scott's trip to five cities in South Africa in November 1996. Scott discussed U.S. accomplishments in space technology, promoted science education, and presented a South African flag, flown in space on the Space Shuttle *Endeavour*, to the deputy president as a symbol of the close relationship between South Africa and the United States. In addition, USIA arranged an August 1997 visit to Peruvian-born astronaut Carlos Noriega's native country, during which he met with Peruvian President Alberto Fujimori and taped 13 antidrug abuse television spots.

USIA's World Wide Web site carried extensive information on NASA activities. Its international home page carried the daily Washington File news service with regular NASA coverage. In addition, the site maintained links to NASA's home page and its daily space photograph.



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] Success	Earth Orbit[a] Failure	Earth Escape[a] Success	Earth Escape[a] 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	24[c,d]	2	1	0
1996	30	1	3	0
1997 *(through September 30, 1997)*	15[e]	0	0	0
TOTAL	1,387	149	89	15

a. The criterion of success or failure used is attainment of Earth orbit or Earth escape rather than judgment of mission success. "Escape" flights include all that were intended to go to at least an altitude equal to lunar distance from 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.
e. This includes the SSTI-Lewis spacecraft that began spinning out of control shortly after it achieved Earth orbit.

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	27[c]	33[b]			1	2[b]			12[b]		1
1996	32[c]	25			1	3[d]			10	1	
1997 (through September 30, 1997)	25	18			1	4			7	1	
TOTAL	1,108	2,543	10	8	51	46	1	1	93	10	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.

d. This includes the launch of ChinaSat 7, even though a third stage rocket failure led to a virtually useless orbit for this communications satellite.

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 1996–September 30, 1997

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Nov. 7, 1996 Mars Global Surveyor 62A Delta II	Remote-sensing mission of Martian atmosphere and soil composition.	Martian orbit	
Nov. 19, 1996 Space Shuttle *Columbia* STS-80 65A Space Shuttle 347 km	Deploy ORFEUS-SPAS and WSF-3 payloads.	358 km 347 km 1 hour 32 min 28.4°	Set record for longest Space Shuttle flight.
Nov. 20, 1996 ORFEUS-SPAS 65B Space Shuttle	Astronomy telescope.	Orbital parameters similar to STS-80	U.S.-German telescope retrieved after several days.
Nov. 23, 1996 WSF-3 65C Space Shuttle	Wake Shield Facility-3, a microgravity module.	Orbital parameters similar to STS-80	Retrieved on November 26, 1996.
Nov. 21, 1996 Hot Bird 2 67A Atlas*	European communications spacecraft.	Geosynchronous	
Dec. 4, 1996 Mars Pathfinder 68A Delta II	Planetary spacecraft with rover to explore Martian surface.		
Dec. 18, 1996 Inmarsat 3 70A Atlas*	Communications satellite.	Geosynchronous	
Dec. 20, 1996 USA 129 72A Titan IV	Military spacecraft.	Orbital parameters unavailable	
Jan. 12, 1997 Space Shuttle *Atlantis* (STS-81) 1A Space Shuttle	Fifth Shuttle mission to *Mir*.	392 km 380 km 1 hour 32 minutes 51.6°	Jerry Linenger replaced John Blaha as U.S. resident on *Mir*.

Appendix B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles
October 1, 1996–September 30, 1997

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Feb. 11, 1997 Space Shuttle *Discovery* (STS-82) 4A Space Shuttle	Second servicing mission of the Hubble Space Telescope.	574 km 475 km 1 hour 35 minutes 28.5°	
Feb. 17, 1997 JCSAT 7A Centaur*	Japanese communications spacecraft.	94,203 km 14,250 km 42 hours 14 minutes 6.3°	
Feb. 24, 1997 USA 130 8A Titan IVB	Military spacecraft.	Orbital parameters unavailable	
Mar. 8, 1997 Tempo 2 11A Atlas IIA*	Communications spacecraft.	Geosynchronous	
Apr. 4, 1997 DMSP F14 (USA 131) 12A Titan II	Military spacecraft.	854 km 843 km 1 hour 42 minutes 98.9°	
Apr. 4, 1997 Space Shuttle *Columbia* (STS-83) 13A Space Shuttle	Deployment of a Spacelab module configured as the first Microgravity Science Laboratory.	303 km 298 km 1 hour 31 minutes 28.4°	A Shuttle fuel cell malfunction necessitated an early termination of the mission. Reflown as STS-94.
Apr. 21, 1997 Minisat 1 18A Pegasus XL*	Spanish microgravity research spacecraft.	581 km 562 km 1 hour 36 minutes 150.9°	
Apr. 25, 1997 GOES-10 19A Atlas-Centaur	Meteorological spacecraft.	Geosynchronous	Will remain passively stored until GOES-8 or GOES-9 becomes inoperational.
May 5, 1997 Iridium 4-8 20A-E Delta II*	Communications spacecraft.	642 km 629 km 1 hour 37 minutes 86.3°	
May 15, 1997 Space Shuttle *Atlantis* (STS-84) 23A Space Shuttle	Sixth Shuttle mission to *Mir*.		Michael Foale replaced Jerry Linenger on *Mir*.

APPENDIX B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 1996–September 30, 1997

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
May 20, 1997 Thor 2A 25A Delta II*	Norwegian communications spacecraft.	Geosynchronous	
July 1, 1997 Space Shuttle *Columbia* (STS-94) 32A Space Shuttle	Reflight of STS-83 and Microgravity Science Laboratory.	299 km 294 km 1 hour 31 minutes 28.5°	Mission proceeded successfully.
July 9, 1997 Iridium 15, 17, 18, 20, and 21 34A-E Delta II*	Communications satellite.	645 km 635 km 1 hour 37 minutes 86.4°	
July 23, 1997 Navstar 43 (USA 132) 35A Delta II	Global Positioning System (GPS) satellite.	20,224 km 19,903 km 11 hours 53 minutes 54.9°	
July 28, 1997 Superbird C 36A Atlas IIAS*	Japanese communications satellite.	Geosynchronous	
Aug. 1, 1997 Orbview 2 37A Pegasus XL*	Ocean monitoring satellite.	319 km 297 km 1 hour 31 minutes 90.7°	Formerly known as Seastar.
Aug. 7, 1997 Space Shuttle *Discovery* (STS-85) 39A Space Shuttle	Deploy CRISTA-SPAS-2 infrared radiation monitor and the Hitchiker package of four experiments on ultraviolet radiation.	309 km 298 km 1 hour 30 minutes 57.0°	The crew also successfully performed the Japanese Manipulator Flight Demonstration of a robotic arm.
Aug. 7, 1997 CRISTA-SPAS-2 39B Space Shuttle	German scientific spacecraft.	Orbital parameters similar to STS-85	Retrieved by Shuttle crew after 9 days of free flight.
Aug. 21, 1997 Iridium 26-22 43A-E Delta II*	Communications satellites.	525 km 505 km 1 hour 35 minutes 95.0°	
Aug. 23, 1997 SSTI-Lewis 44A LMLV-1*	Environmental monitoring satellite.	299.5 km 283.2 km 1 hour 31 minutes 97.6°	A few days after launch, Lewis began spinning uncontrollably and with diminishing solar power.

APPENDIX B

(Continued)

Successful Launches to Orbit on U.S. Launch Vehicles

October 1, 1996–September 30, 1997

Launch Date Spacecraft Name COSPAR Designation Launch Vehicle	Mission Objectives	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Aug. 25, 1997 Advanced Composition Explorer (ACE) 45A Delta II	Space physics scientific spacecraft.	1,256,768 km 179 km 1,398 hours 28.7°	
Aug. 29, 1997 FORTE 47A Pegasus XL	Military arms control spacecraft.	833 km 799 km 1 hour 41 minutes 70.0°	
Sep. 4, 1997 GE-3 50A Atlas IIAS*	Communications satellite.	Geosynchronous	
Sep. 25, 1997 Space Shuttle *Atlantis* (STS-86) 55A Space Shuttle	Seventh Shuttle mission to *Mir*.	392 km 370 km 1 hour 32 minutes 1 hour 32 minutes 51.6°	David Wolf replaced Michael Foale on *Mir*.
Sep. 26, 1997 Iridium 34, 35, 36, 37, and 19 56A-E Delta II*	Communications satellites.	559 km 542 km 1 hour 36 minutes 86.7°	

*Commercial launch licensed as such by the Federal Aviation Administration.

APPENDIX C

U.S. and Russian Human Space Flights
1961–September 30, 1997

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

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 1997

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 demon strated 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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights
1961–September 30, 1997

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	84:1:16	Docked with Skylab 1 in long-duration mission; last of Skylab program.
Soyuz 13	Dec. 18, 1973	Petr I. Klimuk Valentin V. Lebedev	7:20:55	Astrophysical, biological, and Earth resources experiments.
Soyuz 14	July 3, 1974	Pavel R. Popovich 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 (Soyuz 18A)	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.

APPENDIX C

(Continued)

U.S. and Russian Human Space Flights

1961–September 30, 1997

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
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.
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 cosmonaut	May 14, 1981	Leonid I. Popov Dumitru Prunariu	7:20:41	Docked with Salyut 6. Prunariu first Romanian 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 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.

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U.S. and Russian Human Space Flights

1961–September 30, 1997

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz T-8	Apr. 20, 1983	Vladimir Titov Gennady Strekalov Aleksandr Serebrov	2:0:18	Failed to achieve docking with Salyut 7 station.
Space Shuttle *Challenger* (STS-7)	June 18, 1983	Robert L. Crippen Frederick H. Hauck John M. Fabian Sally K. Ride Norman T. Thagard	6:2:24	Seventh flight of Space Shuttle; launched 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 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 Space Flights

1961–September 30, 1997

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 communi cations 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 Space Flights
1961–September 30, 1997

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	June 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

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U.S. and Russian Human Space Flights

1961–September 30, 1997

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 cosmonaut and journalist in space.

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U.S. and Russian Human Space Flights

1961–September 30, 1997

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 Toyohiro Akiyama	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 Krikalevremained on board *Mir*, with Artsebarskiy returning Oct. 10, 1991, and Krikalev doing so Mar. 25, 1992.
Space Shuttle *Columbia* (STS-40)	June 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)	Sep. 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).

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U.S. and Russian Human Space Flights

1961–September 30, 1997

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 in the TM-12 spacecraft.
Space Shuttle *Atlantis* (STS-44)	Nov. 24, 1991	Frederick D. Gregory Tom Henricks Jim Voss Story Musgrave Mario Runco, Jr. Tom Hennen	6:22:51	Forty-fourth STS flight. Launched Defense Support Program (DSP) satellite.
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 on the *Mir* space station.
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)	June 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	July 27, 1992	Anatoly Solovyov Sergei Avdeyev Michel Tognini (France)	189:17:43	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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U.S. and Russian Human Space Flights
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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	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.
Space Shuttle *Endeavour* (STS-57)	June 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 com mercial payload module and retrieved European Retrievable Carrier in orbit since August 1992.

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U.S. and Russian Human Space Flights

1961–September 30, 1997

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz TM-17	July 1, 1993	Vasiliy Tsibliyev Aleksandr Serebrov Jean-Pierre Haignere	196:17:45	Docked with *Mir* space station July 3. Haignere returned to Earth with Soyuz TM-16. Serebrov and Tsibliyev landed in TM-17 spacecraft 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 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 M. Rhea Seddon 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 capabilities and reliability of the Hubble Space Telescope.
Soyuz TM-18	Jan. 8, 1994	Viktor Afanasyev Yuri Usachev Valery Polyakov	182:0:27	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 in cooperation 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.
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	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 body in the first of two ESA missions to *Mir* to prepare for the International Space Station.

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U.S. and Russian Human Space Flights

1961–September 30, 1997

Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
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 atmos pheric 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 Yelena 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.
Space Shuttle *Discovery* (STS-63)	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 ultra-violet telescopes called Astro-2.

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U.S. and Russian Human Space Flights
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Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
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.
Space Shuttle *Columbia* (STS-73)	Oct. 20, 1995	Kenneth D. Bowersox Kent V. Rominger Catherine G. Coleman Michael Lopez-Alegria Kathryn C. Thornton Fred W. Leslie Albert Sacco, Jr.	15:21:52	Seventy-second STS flight. Carried out microgravity experiments with the U.S. Microgravity Laboratory (USML-2) payload.
Space Shuttle *Atlantis* (STS-74)	Nov. 12, 1995	Kenneth D. Cameron James D. Halsell, Jr. Chris A. Hadfield (CSA) Jerry L. Ross William S. McArthur, Jr.	8:4:31	Seventy-third STS flight. Docked with *Mir* space station as part of International Space Station (ISS) Phase I efforts.
Space Shuttle *Endeavour* (STS-72)	Jan. 11, 1996	Brian Duffy Brent W. Jett, Jr. Leroy Chiao Winston E. Scott Koichi Wakata (Japan) Daniel T. Barry	8:22:1	Seventy-fourth STS flight. Deployed OAST Flyer. Retrieved previously launched Japanese Space Flyer Unit satellite. Crew performed spacewalks to build experience for ISS construction.
Soyuz TM-23	Feb. 21, 1996	Yuri Onufrienko Yuri Usachyou	*	Soyuz TM-22 returned to Earth on Feb. 29, 1996, with *Mir* 20 crew (Yuri Gidzenko, Sergei Avdeev, and Thomas Reiter).

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U.S. and Russian Human Space Flights

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Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Space Shuttle *Columbia* (STS-75)	Feb. 22, 1996	Andrew M. Allen Scott J. Horowitz Jeffrey A. Hoffman Maurizio Cheli (ESA) Claude Nicollier (ESA) Franklin R. Chang-Diaz Umberto Guidoni (ESA)	13:16:14	Seventy-fifth STS flight. Deployed Tethered Satellite System, U.S. Microgravity Payload (USMP-3), and protein crystal growth experiments.
Space Shuttle *Atlantis* (STS-76)	Mar. 22, 1996	Kevin P. Chilton Richard A. Searfoss Linda M. Godwin Michael R. Clifford Ronald M. Sega Shannon W. Lucid**	9:5:16	Seventy-sixth STS flight. Docked with *Mir* space station and left astronaut Shannon Lucid aboard *Mir*. Also carried SPACEHAB module.
Space Shuttle *Endeavour* (STS-77)	May 19, 1996	John H. Casper Curtis L. Brown Andrew S. W. Thomas Daniel W. Bursch Mario Runco, Jr. Marc Garneau (CSA)	10:2:30	Seventy-seventh STS flight. Deployed SPARTAN/Inflatable Antenna Experiment, SPACEHAB, and PAMS-STU payloads.
Space Shuttle *Columbia* (STS-78)	June 20, 1996	Terrence T. Henricks Kevin Kregel Richard M. Linnehan Susan J. Helms Charles E. Brady, Jr. Jean-Jacques Favier (CSA) Robert B. Thirsk (ESA)	16:21:48	Seventy-eighth STS flight. Set Shuttle record for then-longest flight. Carried Life and Microgravity Sciences Spacelab.
Soyuz TM-24	Aug. 17, 1996	Claudie Andre-Deshays (ESA) Valery Korzun Alexander Kaleri	*	Soyuz TM-23 returned to Earth on Sep. 2, 1996, with Claudie Andre-Deshays, Yuri Onufrienko, and Yuri Usachev.
Space Shuttle *Atlantis* (STS-79)	Sep. 16, 1996	William F. Readdy Terrence W. Wilcutt Jerome Apt Thomas D. Akers Carl E. Walz John E. Blaha** Shannon W. Lucid***	10:3:19	Seventy-ninth STS flight. Docked with *Mir* space station. Picked up astronaut Shannon Lucid and dropped off astronaut John Blaha.
Space Shuttle *Columbia* (STS-80)	Nov. 19, 1996	Kenneth D. Cockrell Kent V. Rominger Tamara E. Jernigan Thomas David Jones F. Story Musgrave	17:15:53	Set record for longest Shuttle flight. At age 61, Musgrave became oldest person to fly in space. He also tied record for most space flights (six) by a single person. Crew successfully deployed ORFEUS-SPAS II ultraviolet observatory and Wake Shield Facility payloads.
Space Shuttle *Atlantis* (STS-81)	Jan. 12, 1997	Michael A. Baker Brent W. Jett Peter J.K. "Jeff" Wisoff John M. Grunsfeld Marsha S.Ivins Jerry M. Linenger** John E. Blaha***	10:4:56	Fifth Shuttle mission to *Mir*. Jerry Linenger replaced John Blaha as U.S. resident on *Mir*.

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Spacecraft	Launch Date	Crew	Flight Time (days:hrs:min)	Highlights
Soyuz TM-25	Feb. 10, 1997	Vasily Tsibliyev Aleksandr Lazutkin Reinhold Ewald	*	Soyuz TM-24 returned to Earth on March 2, 1997, with Reinhold Ewald, Valery Korzun, and Alexandr Kaleri.
Space Shuttle *Discovery* (STS-82)	Feb. 11, 1997	Kenneth D. Bowersox Scott J. Horowitz Joseph R. Tanner Steven A. Hawley Gregory J. Harbaugh Mark C. Lee Steven L. Smith	9:23:36	Crew successfully performed second servicing mission of the Hubble Space Telescope.
Space Shuttle *Columbia* (STS-83)	Apr. 4, 1997	James D. Halsell, Jr. Susan L. Still Janice Voss Michael L. Gernhardt Donald A. Thomas Roger K. Crouch Gregory T. Linteris	3:23:34	Crew deployed a Spacelab module configured as the first Microgravity Science Laboratory. Shuttle fuel cell malfunction necessitated an early termination of the mission.
Space Shuttle *Atlantis* (STS-84)	May 15, 1997	Charles J. Precourt Eileen Marie Collins Jean-François Clervoy Carlos I. Noriega Edward Tsang Lu Elena V. Kondakova Michael Foale** Jerry M. Linenger***	9:5:21	Sixth Shuttle mission to *Mir*. Michael Foale replaced Jerry Linenger on *Mir*.
Space Shuttle *Columbia* (STS-94)	July 1, 1997	James D. Halsell, Jr. Susan L. Still Janice Voss Michael L. Gernhardt Donald A. Thomas Roger K. Crouch Gregory T. Linteris	15:16:45	Reflight of STS-83 and the same payload, the Microgravity Science Laboratory. Mission proceeded successfully.
Soyuz TM-26	Aug. 5, 1997	Anatoly Solovyev Pavel Vinogradov	*	Soyuz TM-25 returned to Earth on August 14, 1997, with Vasily Tsibliev and Alesandr Lazutkin.
Space Shuttle *Discovery* (STS-85)	Aug. 7, 1997	Curtis L. Brown, Jr. Kent V. Rominger N. Jan Davis Robert L. Curbeam, Jr. Stephen K. Robinson Bjarni V. Tryggvason	11:20:27	Crew successfully deployed two payloads: CRISTA-SPAS-2 on infrared radiation and an international Hitchhiker package of four experiments on ultraviolet radiation. The crew also successfully performed the Japanese Manipulator Flight Demonstration of a robotic arm.
Space Shuttle *Atlantis* (STS-86)	Sep. 25, 1997	James D. Wetherbee Michael J. Bloomfield Scott E. Parazynski Vladimir Titov Jean-Loup Chretien Wendy B. Lawrence David A. Wolf** C. Michael Foale***	10:19:21	Seventh Shuttle docking with *Mir*. David Wolf replaced Michael Foale on *Mir*. Parazynski and Titov performed a spacewalk to retrieve four *Mir* Environmental Effects Payload experiments from the exterior of the docking module and left a solar array cover cap for possible future repair of the damaged *Spektr* module.

* *Mir* crew members stayed for various and overlapping lengths of time.
** Flew up on Space Shuttle; remained in space aboard Russian *Mir* space station.
*** Returned to Earth via Space Shuttle from Russian *Mir* space station.

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[b, c]	Max. Dia x Height (m)	Max. Payload (kg)[d] 185-km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[e]	First Launch[f]
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	1,400 1,080[e]	255	1,020	Not scheduled
	0. Castor 120	Solid	1,687.7	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	5,089 3,890[e]	1,842[i]	3,175	1990, Delta-7925 [1960, Delta]
	1. RS-270/A	LOX/RP-1	1,043.0 (SL)	3.05x38.1				
	Hercules GEM (9)	Solid	487.6 (SL)	1.01x12.95				
	2. AJ10-118K	N204/A-50	42.4	2.44x5.97				
	3. Star 48B[j]	Solid	66.4	1.25x2.04				
Atlas E				3.05x28.1	820[e] 1,860[e, k]	—	910[k]	1968, Atlas F [1958, Atlas LV-3A]
	1. Atlas: MA-3	LOX/RP-1	1,739.5 (SL)	3.05x21.3				
Atlas I				4.2x43.9	—	2,255	—	1990, I [1966, Atlas Centaur]
	1. Atlas: MA-5	LOX/RP-1	1,952.0 (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	6,580 5,510[e]	2,810	4,300	1991, II [1966, Atlas Centaur]
	1. Atlas: MA-5A	LOX/RP-1	2,110.0 (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	6,828 6,170[e]	3,062	4,750	1992, Atlas IIA [1966, Atlas Centaur]
	1. Atlas: MA-5A	LOX/RP-1	2,110.0 (SL)	3.05x24.9				
	2. Centaur II: RL10A-4 (2)	LOX/LH_2	92.53/engine	3.05x10.05				
Atlas IIAS				4.2x47.5	8,640 7,300[e]	3,606	5,800	1993, IIAS [1966, Atlas Centaur]
	1. Atlas: MA-5A	LOX/RP-1	2,110.0 (SL)	3.05x24.9				
	Castor IVA (4)[i]	Solid	433.6 (SL)	1.01X11.16				
	2. Centaur II: RL10A-4 (2)	LOX/LH_2	92.53/engine	3.05x10.05				

(Continued)

U.S. Space Launch Vehicles

Vehicle	Stages: Engine/Motor	Propellant[a]	Thrust (kilonewtons)[b, c]	Max. Dia x Height (m)	Max. Payload (kg)[d] 185-km Orbit	Geosynch. Transfer Orbit	Sun-Synch. Orbit[e]	First Launch[f]
Titan II				3.05x42.9	1,905[e]	—	—	1988, Titan II SLV [1964, Titan II Gemini]
	1. LR-87-AJ-5 (2)	N204/A-50	1,045.0	3.05x21.5				
	2. LR-91-AJ-5	N204/A-50	440.0	3.05x12.2				
Titan III				3.05x47.3	14,515	5,000[l]	—	1989, Titan III [1964, Titan IIIA]
	0. Titan III SRM (2) (5-1/2 segments)	Solid	6,210.0	3.11x27.6				
	1. LR87-AJ-11 (2)	N204/A-50	1,214.5	3.05x24.0				
	2. LR91-AJ-11	N204/A-50	462.8	3.05x10.0				
Titan IV				3.05x62.2	17,700 14,110[e]	6,350[m]	—	1989, Titan IV
	0. Titan IV SRM (2) (7 segments)	Solid	7,000.0	3.11x34.1				
	1. LR87-AJ-11 (2)	N204/A-50	1,214.5	3.05x26.4				
	2. LR91-AJ-11	N204/A-50	462.8	3.05x10.0				
Titan IV/				4.3x62.2	—	5,760[a]	—	1994, Titan IV Centaur
	0. Titan IV SRM (2) (7 segments)	Solid	7,000.0	3.11x34.1				
	1. LR87-AJ-11 (2)	N204/A-50	1,214.5/engine	3.05x26.4				
	2. LR91-AJ-11(1)	N204/A-50	462.5	3.05x10.0				
	3. Centaur: RL-10A-3-3A	LOX/LH2	73.4	4.3x9.0				
	4. SRMU (3 segments)		7690	3.3x34.3				
Space Shuttle[n]				23.79x56.14[h]	24,900[o]	5,900[p]	—	1981, *Columbia*
	1. SRB: Shuttle SRB (2)	Solid	11,790.0 (SL)	3.70x45.46				
	2. Orbiter/ET: SSME (3)	LOX/LH_2	1,668.7 (SL)	8.41x47.00 (ET) 23.79x37.24[h] (orbiter)				
	3. Orbiter/OMS: OMS engines (2)	N_2O_4/MMH	26.7	23.79x37.24[h]				

APPENDIX D

(Continued)

U.S. Space Launch Vehicles

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_2O_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.

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's continuing 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 or Transfer Orbit Stage.

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

Space Activities of the U.S. Government

HISTORICAL BUDGET SUMMARY—BUDGET AUTHORITY
(in millions of real-year dollars)

FY	NASA Total	NASA Space[b]	DoD	Other[c]	DoE	DoC	DoI	USDA	NSF[a]	DoT	EPA[d]	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
TQ*	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	233	40	93	12	14	74			8,761
1981	5,518	4,992	4,828	233	41	87	12	16	77			10,053
1982	6,044	5,528	6,679	311	61	145	12	15	78			12,518
1983	6,875	6,328	9,019	325	39	178	5	20	83			15,672
1984	7,458	6,858	10,195	392	34	236	3	19	100			17,445
1985	7,573	6,925	12,768	580	34	423	2	15	106			20,273
1986	7,807	7,165	14,126	473	35	309	2	23	104			21,764
1987	10,923	9,809	16,287	462	48	278	8	19	108	1		26,558
1988	9,062	8,322	17,679	737	241	352	14	18	111	1		26,738
1989	10,969	10,097	17,906	560	97	301	17	21	116	3	5	28,563
1990	12,324	11,460	15,616	512	79	243	31	25	125	4	5	27,588
1991	14,016	13,046	14,181	697	251	251	29	26	131	4	5	27,924
1992	14,317	13,199	15,023	769	223	327	34	29	145	4	7	28,991
1993	14,310	13,064	14,106	698	165	324	33	25	139	4	8	27,868
1994	14,570	13,022	13,166	601	74	312	31	31	140	5	8	26,789
1995	13,854	12,543	10,644	629	60	352	31	32	141	6	7	23,816
1996	13,884	12,569	11,514	750	46	472	36	37	147	6	6	24,833
1997	13,709	12,457	11,727	727	35	448	42	39	151	6	6	24,911

* Transition Quarter

a. NSF has recalculated its space expenditures since 1980, making them significantly higher than reported in previous years.

b. Includes $2.1 billion for replacement of Space Shuttle *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 in 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 1997 DOLLARS
(adjusted for inflation)

FY	Inflation Factors	NASA Total	NASA Space	DoD	Other	DoE	DoC	DoI	USDA	NSF	DoT	EPA	Total Space
1959	4.8506	1,606	1,266	2,377	165	165							3,808
1960	4.7579	2,493	2,198	2,669	205	205				0.5			5,072
1961	4.7149	4,545	4,366	3,838	325	321				5			8,529
1962	4.6469	8,481	8,350	6,032	929	688	237			5			15,311
1963	4.5942	16,875	16,659	7,121	1,190	983	198			9			24,970
1964	4.5409	23,159	22,777	7,261	981	954	14			14			31,019
1965	4.4796	23,518	23,016	7,051	1,093	1,026	54			13			31,160
1966	4.4057	22,800	22,315	7,441	956	824	119			13			30,712
1967	4.3070	21,388	20,803	7,167	930	792	125			13			28,900
1968	4.1756	19,154	18,498	8,026	740	605	117	0.8	4	13			27,263
1969	4.0223	16,053	15,373	8,097	568	475	80	0.8	4	8			24,038
1970	3.8525	14,431	13,665	6,464	443	397	31	4	4	8			20,572
1971	3.6594	12,116	11,348	5,533	465	348	99	7	4	7			17,346
1972	3.4803	11,510	10,688	4,897	338	191	108	21	7	10			15,923
1973	3.3220	11,315	10,275	5,392	362	179	133	33	7	10			16,029
1974	3.1821	9,664	8,779	5,620	369	134	191	29	10	6			14,768
1975	2.9674	9,582	8,650	5,614	315	89	190	24	6	6			14,579
1976	2.6904	9,551	8,677	5,335	299	62	194	27	11	5			14,310
TQ	2.5092	2,339	2,130	1,154	80	13	55	8	3	3			3,365
1977	2.4307	9,280	8,362	5,863	318	53	221	24	15	5			14,543
1978	2.3318	9,467	8,448	6,385	366	79	240	23	19	5			15,199
1979	2.1783	10,012	8,779	6,613	386	129	213	22	17	4			15,778
1980	2.0119	10,542	9,416	7,742	469	80	187	24	28	149			17,626
1981	1.8476	10,195	9,223	8,920	430	76	161	22	30	142			18,574
1982	1.6819	10,166	9,298	11,234	523	103	244	20	25	131			21,054
1983	1.5709	10,800	9,941	14,168	511	61	280	8	31	130			24,620
1984	1.5016	11,199	10,298	15,309	589	51	354	5	29	150			26,195
1985	1.4457	10,948	10,011	18,459	839	49	612	3	22	153			29,309
1986	1.3976	10,911	10,013	19,742	661	49	432	3	32	145			30,416
1987	1.3589	14,843	13,329	22,132	628	65	378	11	26	147	1		36,089
1988	1.3207	11,968	10,991	23,349	973	318	465	18	24	147	1		35,313
1989	1.2764	14,001	12,888	22,855	715	124	384	22	27	148	4	6	36,457
1990	1.2246	15,092	14,034	19,123	627	97	298	38	31	153	5	6	33,784
1991	1.1758	16,480	15,340	16,674	820	295	295	34	31	154	5	6	32,833
1992	1.1274	16,141	14,880	16,937	867	251	369	38	33	163	5	8	32,684
1993	1.0984	15,718	14,349	15,494	767	181	356	36	27	153	4	9	30,610
1994	1.0725	15,626	13,966	14,120	645	79	335	33	33	150	5	9	28,731
1995	1.0456	14,486	13,115	11,130	657	63	368	32	33	147	6	7	24,902
1996	1.0220	14,190	12,846	11,768	767	47	482	37	38	150	6	6	25,380
1997	1.0000	13,709	12,457	11,727	727	35	448	42	39	151	6	6	24,911

SOURCE: Office of Management and Budget

Federal Space Activities Budget

(in millions of dollars by fiscal year)

Federal Agencies	Budget Authority			Budget Outlays		
	1995 actual	1996 actual	1997 est.	1995 actual	1996 actual	1997 est.
NASA	12,543	12,569	12,457	12,593	12,694	13,055
Defense	10,644	11,514	11,727	11,494	11,353	11,959
Energy	60	46	35	70	46	37
Commerce	352	472	448	330	354	336
Interior	31	36	42	31	36	42
Agriculture	32	37	39	32	37	39
Transportation	6	6	6	5	6	6
EPA	7	6	6	7	7	6
NSF	141	147	151	138	142	146
TOTAL	23,816	24,833	24,911	24,700	24,675	25,626

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		
	1995 actual	1996 actual	1997 est.	1995 actual	1996 actual	1997 est.
NASA[a]	1,310	1,315	1,252	1,143	1,187	1,302
Defense[b]	7,196	6,792	6,323	7,132	6,974	6,600
Transportation[c]	2,212	2,052	2,146	2,870	2,676	2,528
TOTAL	10,718	10,159	9,721	11,145	10,837	10,430

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.

Glossary

ACDA Arms Control and Disarmament Agency
ACE Advanced Composition Explorer
ACTS Advanced Communications Technology Satellite
ADEOS Advanced Earth Observing Satellite (Japan)
AEB Brazilian space agency
AFB Air Force Base
AGRE Active Geophysical Rocket Experiment
AMOS Air Force Maui Optical Site
ARS Agricultural Research Service (USDA)
ASTP Apollo-Soyuz Test Project
ATLAS Atmospheric Laboratory for Applications and Science
AVHRR Advanced Very High Resolution Radiometer
AXAF Advanced X-ray Astrophysics Facility

BIA Bureau of Indian Affairs (DoI)
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)

CIA Central Intelligence Agency

CIS Commonwealth of Independent States

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

COSPAR Congress for Space Research

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

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

DoS Department of State

DoT Department of Transportation

DSP Defense Support Program

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

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

EOSDIS EOS Data and Information System

EPA Environmental Protection Agency

EROS Earth Resources Observation System (USGS)

ESA European Space Agency

EU European Union

EUMETSAT European Union for the Exploitation of Meteorological Satellites

EVA Extravehicular activity

FAA Federal Aviation Administration

FAS Foreign Agricultural Service (USDA)

FCC Federal Communications Commission

FIRS-2 Far Infrared Spectrometer 2

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

Free flight A concept being developed by the FAA and the aviation community in which pilots could ultimately choose their own routes, speeds, and altitudes in flight, thus improving safety, while saving fuel, time, and natural resources

FSA Farm Service Agency (USDA)

FY Fiscal year

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

GATT General Agreements on Tariffs and Trade

GE General Electric Company

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

Geosynchronous geostationary

GIS Geographic Information System

GOES Geostationary Operational Environmental Satellite

GPHS General purpose heat source

GPS Global Positioning System

GPS-MET GPS-Meteorological (experiment)

GRACE Gravity Recovery And Climate Experiment

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

HST Hubble Space Telescope

Hypersonic Faster than Mach 4 and faster than "high speed"

Hyperspectral An instrument capability using many very narrow spectral frequency bands (300 or more), enabling a satellite-based passive sensor to discriminate specific features or phenomena on the body being observed (e.g., Earth)

ICBM Intercontinental ballistic missile

IGOS Integrated Global Observing Strategy

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 the exchange of electronic information

Ionosphere That region of Earth's atmosphere so named because of the presence of ionized atoms in layers that reflect radio waves and shortwave transmissions

IRS Indian Remote Sensing (satellite)

ISO International Organization for Standardization

ISS International Space Station

ITA International Trade Administration

IVA Intravehicular vehicle

JCSAT Japanese Communications Satellite

JPL Jet Propulsion Laboratory (NASA)

K-band Radio frequencies in the 20-gigahertz range

Ka-band Radio frequencies in the 30-gigahertz range

Km kilometer

Ku-band Radio frequencies in the 11–12 gigahertz range

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

Laser Light amplified by simulated emission of radiation—a device that produces an intense beam of light that may be strong enough to vaporize the hardest and most heat-resistant materials, first constructed in 1960

LDEF Long-Duration Exposure Facility

LH_2 Liquid hydrogen

LOX Liquid oxygen

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 equals approximately 741 mph or 1,192 kilometers per hour

Mach See M

Magnetosphere The region of Earth's atmosphere in which 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 Earth's

MMH Monomethyl hydrazine

MMS Minerals Management Service (DoI)

MSS Multispectral Scanner (Landsat instrument)

MSTI Miniature Sensor Technology Integration
MSX Midcourse Space Experiment (BMDO)
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
NAS National Airspace System (FAA)
NASA National Aeronautics and Space Administration
NASDA National Space Development Agency (of Japan)
NASS National Agricultural Statistics Service (USDA)
NDOP National Digital Orthophoto Program
NEAR Near Earth Asteroid Rendezvous
Neutron star Any of a class of extremely dense, compact stars thought to be composed primarily of neutrons; see pulsar
NIMA National Imagery and Mapping Agency
NOAA National Oceanic and Atmospheric Administration (DoC); also the designation of that administration's Sun-synchronous satellites in polar orbit
nominal Functioning as designed
NPS National Park Service (DoI)
NRCS National Resources Conservation Service (USDA)
NRO National Reconnaissance Office (DoD)
NSF National Science Foundation
NTIA National Telecommunications and Information Administration (DoC); the Federal Government's radio spectrum manager, which coordinates the use of low-Earth orbit (100 to 350 nautical miles above Earth) satellite networks, such as those for Landsat, Navstar GPS, the Space Shuttle, and TIROS, with other countries of the world

OA Office of Aerospace (DoC-ITA)
OASC Office of Air and Space Commercialization (DoC)
OAST Office of Aeronautics and Space Technology (NASA)
ODERACS Orbital Debris Radar Calibration Spheres
OLMSA Office of Life and Microgravity Sciences and Applications (NASA)
order of magnitude An amount equal to 10 times a given value; thus if some quantity was 10 times as great as another quantity, it would be an order of magnitude greater; if 100 times as great, it would be larger by two orders of magnitude
ORFEUS-SPAS Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph-Shuttle Pallet Satellite
OT Office of Telecommunications (DoC-ITA)

PAMS-STU Passive Aerodynamically stabilized Magnetically Damped Satellite-Satellite Test Unit
PAS PanAmSat
Photogrammetry The science or art of obtaining reliable measurements by means of photography
POES Polar-orbiting Operational Environmental Satellite (program)
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
RP-1 Rocket Propellant 1 (kerosene)
RSRU Remote Sensing Research Unit (USDA)
RTG Radioisotope thermoelectric generator

SAO Smithsonian Astrophysical Observatory
SAR Synthetic Aperture Radar
Scramjet Supersonic-combustion ramjet
SLBM Submarine-launched ballistic missile
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
SPACEHAB Commercial module for housing Shuttle experiments
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)
SRB Solid Rocket Booster
SSBUV Shuttle Solar Atmosphere Backscatter Ultraviolet (spectrometer)
SSCE Solid Surface Combustion Experiment
SSME Space Shuttle Main Engine
START Strategic Arms Reduction Treaty
STS Space Transportation System

TDRS Tracking and Data Relay Satellite
TM Thematic Mapper (Landsat instrument)

UARS Upper Atmosphere Research Satellite
U.N. United Nations
U.S. United States
USDA U.S. Department of Agriculture
USGS U.S. Geological Survey (DoI)
USIA U.S. Information Agency
USML U.S. Microgravity Laboratory
USMP U.S. Microgravity Payload

VHF Very High Frequency; any radio frequency between 30 and 300 megacycles per second
VOA Voice of America

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

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

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★ U.S. GOVERNMENT PRINTING OFFICE: 1998 – 433-387 / 96503